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THE UNITED STATES COAST SURVEY.

By GEO. L. VOSE, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

The frequenter of any of our larger libraries may have seen upon the lowest shelf of some out-of-the-way alcove a group of substantial quartos clothed in solemn black and wedged tightly in by other heavy volumes, all of them bearing the most unmistakable evidence of enjoying a dignified repose and of being very seldom called for. If the visitor should draw out one of these huge quartos, blow the dust from the upper edges of the leaves and lay the volume open, he would find, perhaps, half its thickness taken up by various maps, any one of which, should he be rash enough to unfold it, will be a good exercise of his skill and patience to fold up again. If he turns to the text he will find himself involved in a mass of complex formula and elaborate discussions of various highly scientific subjects, the very language of which, for the most part, he will fail to comprehend. By this time he will be very apt to have seen enough, and will gladly return the volume to its resting-place, where it will continue its long slumber and accumulate a new coating of dust.

This group of neglected volumes cannot be purchased for any money. Probably no man except the proof reader has ever read one of them through, and yet they are a mine of wealth to the student of science, a noble monument of consummate skill and of patient industry, of long-continued toil and untiring devotion to duty. Learned men the world over have been glad to do honor to the authors. The results recorded are of immense importance alike to the farmer, the merchant, and the manufacturer. We have moreover in these volumes a remarkable example of the practical importance of the most abstract scientific research; an illustration of the general law that the conscientious investigation of truth for its own sake shall be rewarded by some unforeseen practical benefit. The works to which we refer are the "Reports of the United States Coast Survey," and from these documents and other scientific publications we propose to extract such facts as will show to the reader something of the objects, the methods and the results of the organization which has employed the best scientific talent of America for upwards of twenty years, and has produced results which are no less remarkable for their high scientific character than valuable to the industry of the country.

That commerce is of vast importance to any nation, and especially so to an isolated country like America, the reader does not need to be told, nor will he fail to see that the more the risks attending navigation are reduced, the better, not only for those directly engaged in

commerce, but also for *producers* in every part of the land. Indeed, so closely interwoven are the different branches of human industry that what affects commerce affects all. The results of the Coast Survey are thus not less important to the interior than to the seaboard states.

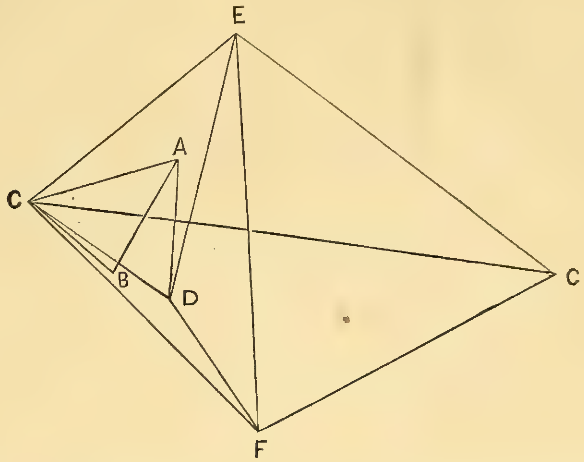
Prominent, if not chief, among the dangers of the deep are the reefs and shoals, the tides and currents that fringe the borders of the land. With a plenty of room and deep water the sailor has comparatively little to fear. It is, therefore, of special importance that the outline of the coast should be mapped with the utmost exactness, and more than this, that the knowledge of the nature and shape of the bottom from the shore out to the deep sea should be very complete, the more so as all beneath the water is hidden from sight and can only be shown to the navigator by correctly prepared charts. In clear weather, even though it be night, we may find no difficulty in working into a harbor provided with suitable beacons and lights; but in stormy weather, and worse yet, when all signals are swallowed up by impenetrable mists, the case is very different, and just here is where the admirable charts of the Coast Survey come in to take the tired mariner by the hand and lead him amongst rocks and shoals and shifting currents to an anchorage where he may lay firm hold of the land, safe from the dangers of the deep.

The two principal objects of the Coast Survey are thus plainly seen, viz.—first, to make an absolutely exact map of the outline of the coast, and, second, to prepare charts, which extending from the coast line out to deep water shall give the sailor as clear a knowledge of the nature and shape of the bottom as if the sea was drawn off and its bed laid bare.

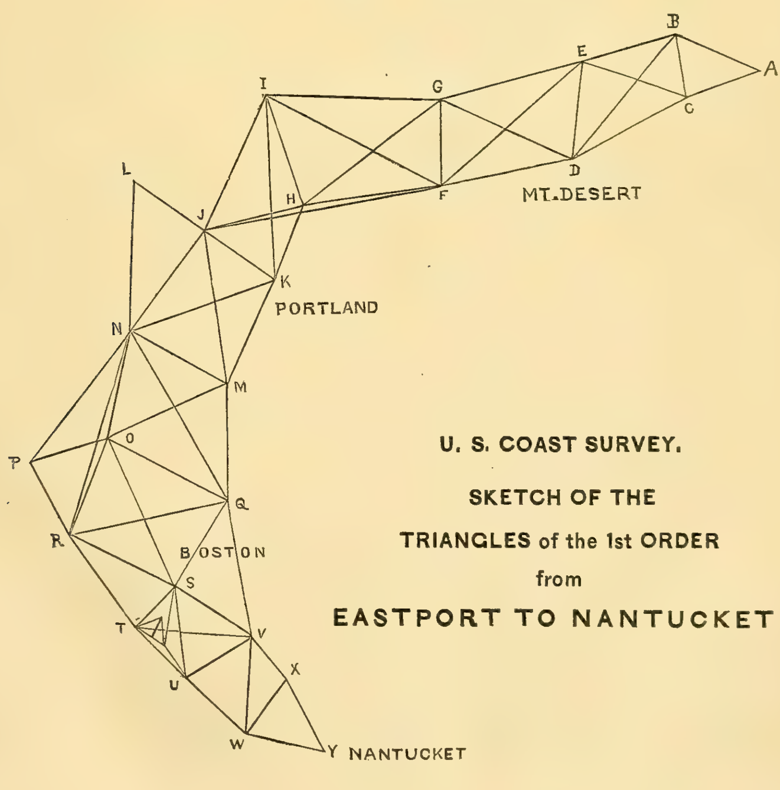
For the determination of points upon a coast reaching over many degrees of latitude the ordinary methods of surveying are not at all applicable. Surveys made upon the assumption that the surface of the earth is a plane would be so incorrect as to be worse than useless; and not only is it necessary to take into account the spherical form of the globe, but still farther the flattening of the sphere at the poles must be regarded or we do not obtain a sufficiently exact result. All of this precision in the requirement demand a corresponding amount of scientific knowledge and practical skill in the execution of the work. In fact, the making of the outline map of the coast has drawn upon all departments of Astronomy and Physics, and not only has the Coast Survey availed itself of all that was known, but it has invented new instruments and new methods of observation and of computation which have been adopted by astronomers both in this country and in Europe.

It will be evident at the outset that it would be impracticable, if not impossible, to determine the distance from point to point along the coast by direct measurement with a chain or other apparatus; for not only would such a line pass through swamps and woods and even into the water, but following the general trend of the coast it would be very crooked, and unless each change of direction was exactly determined we should not only make errors in the position of our line, but such errors would be carried along, and accumulating, would so distort the survey that when we undertook to lay our work upon the plans we should find a wide difference between the position of the various points as given by our measurements, and the position of the same points as determined by fixing their latitude and longitude by astronomical observation. The methods employed for locating the principal points along the coast avoids all such errors, and also saves much time and expense. The principle involved is the most elementary one in Trigonometry, viz.—that when we know one side of a triangle and two angles we can compute the remaining side. An extension of this simple principle, carried out, of course, with all the refinements of modern science, gives what is termed the Primary Triangulation, the extent and nature of which will be understood from the following sketches, in which Fig. 1 shows the commencement of the work resting on the Massachusetts Base, and Fig. 2 the whole system from Eastport to Nantucket. In Fig. 1 AB is a line on the Boston and Providence Railroad about ten miles long, measured with the utmost accuracy as hereafter described. From C, A, and B the several angles of the triangle ABC are measured, and thus the remaining sides AC and

BC become known. Next, from the stations D, A, and C the angles of the triangle ACD are measured, and also two angles of the triangle CDE, E being a station on one of the Blue Hills in Milton. From this point, as well as



from C, angles are measured to F and G, and by computation the lengths of all the lines represented in the sketch become as accurately known as if they had been measured directly. In the same way the triangulation is continued as in Fig. 2, which shows the triangles of the first order from Passamaquoddy



Bay to Nantucket, A being the Grand Menan, D Mount Desert, F Ragged Mountain, at Camden, I Mount Blue, at Farmington, J Pleasant Mountain, in Denmark, K Mount Independence, near Portland, L Mount Washington, M Agamenticus, near Portsmouth, N Gunstock, at Lake Winnepesaukee, O Unkonoonuc, near Manchester, P Monadnoc, in Cheshire County, N. H., Q Thompson's Hill, Gloucester, R Wachusett, in Princeton, S Blue Hill, in Milton, T Beaconpole, U Copecut Hill, V Manomet, W Indian Hill, on Martha's Vineyard, X a station on Cape Cod, and Y a point on Nantucket. The Massachusetts Base with its triangles is shown at T, but on a very small scale.

By this method of proceeding we fix the position of the several points with great exactness, regarding both the globular form of the earth and also the flattening of the globe at the poles; and when we say with great exactness we mean within a few inches. It may be asked how we know that our points are within so short a distance of being absolutely correct. We know it by selecting a suitable place on the ground near the end of our series of triangles and measuring a line five or six miles long with the utmost care. This line is then connected with our primary triangulation so that we can also obtain its length, independently of actual measurement, by computation. The calculated and measured lengths should, of course, be alike. Such a line is called a Base of Verification, and when it is remembered that a single false step in the whole immense chain of triangles would prevent this final agreement, we can appreciate the splendid practical science of the officers of our Coast Survey, which starting from its primary base and working through a chain of triangles over three hundred miles long, should vary no more than three or four inches in a base of verification five and one-half miles in length. Such results as this are, of course, only obtained by long-continued observations, with the most refined instruments, in the hands of the most skillful observers. The base of verification for the New England chain of triangles is a line about five and one-half miles long on Epping Plains, in Maine, and is shown in Fig. 2 by the short heavy line in the triangle CDE. The triangles connecting this line with the points C, D, and E are not shown on account of the small scale to which our figure is drawn.

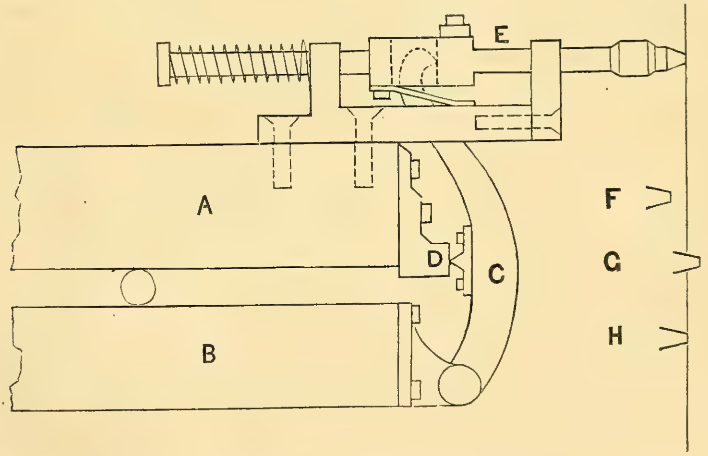
It will be observed that the triangles in Fig. 2 are very large, the sides of some of them being as long as seventy miles. This is desirable, in order that the number of measurements may be few as possible, and the chance of error reduced. The large theodolite used in the measurement of angles has a thirty-inch circle divided to five minutes, and reading by the microscopes to single seconds. The telescope is of great power and partly suppported by springs within the upright columns, which bear the axis to relieve the bearings from friction. The weight of the upper part is to a considerable extent borne by friction rollers, which, taking the weight from the vertical axis, allow a very easy horizontal motion. This fine theodolite was designed by Mr. Hassler and made by Troughton & Simms, of London. There are many causes of slight error even with the best instruments in measuring an angle. Indeed, it is not possible to measure an angle with absolute correctness; but by multiplying the observations the error is reduced to a very small amount, and mathematicians can tell with certainty what the probable error will be from any number of observations. With the large theodolite above mentioned the probable error of a single measurement of an angle is about one and one-fourth seconds, and the mean of thirty measurements, the usual number made, about one-fourth of a second.

In order to measure exactly an angle between two points these points must be very closely defined. For short distances and ordinary work the signal employed by the Coast Survey is a cone of tin fastened on top of a pole; but for the larger triangles and for long distances an instrument called a heliotrope is used. This consists of a small mirror so mounted with a telescope that the reflection of the sun may be thrown in any desired direction. This reflection will often be seen eighty or ninety miles away when the outlines of mountains are entirely invisible on account of haze. The heliotrope is also used for telegraphic com-

munication; as by passing the hand rapidly in front of it the reflection is for a moment cut off, and a code of signals made by a combination of short and long flashes has been found sufficient for transmitting messages.

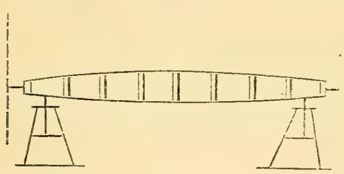
By what has preceded it will be seen that every thing in the Primary Triangulation depends upon the accuracy with which the Base Line is measured. Now, while we can easily measure an angle over a hundred times, if necessary to ensure accuracy, we cannot repeat so many times the measurement of a line without consuming unwarrantable time. Again, as the base which may be ten or twelve miles long is measured with a bar not more then twenty feet in length; if the bar is not exactly correct we shall multiply the error, say three thousand times. Thus it is that the correct measurement of the base line is an object of so much importance, and that the construction of the apparatus calls for all the skill both of the designer and the maker. A simple iron bar may be used for the measurement of distances, but such a bar is affected to a greater or less extent by heat, and although we may keep a record of the temperature, the thermometer becomes heated much sooner than the bar, and thus does not give the correct allowance to be made for the expansion of the metal. To overcome this difficulty the compensation obtained by combining two different metals may be employed, but we shall still make an error, as different metals do not undergo equal changes of temperature in equal times, on account of the different absorbing powers of their surfaces, their different powers of conducting heat from the surface to the interior of the mass and the difference in the total quantity of heat which they can take up, or their specific heats. The same coating of varnish upon both bars will give them equal absorbing powers; and by so arranging the sections of the two bars that while the amount of surface is the same the masses shall be inversely as the specific heats, a small allowance being also made for their different conducting rates, a system is formed which not only retains the same length at all temperatures, but what is no less important, during all changes of temperature.

We give in Fig. 3 a sketch, half full size, showing one end of the base apparatus as finally arranged for use on the Coast Survey. A bar of brass and a bar of iron, each about twenty feet long,

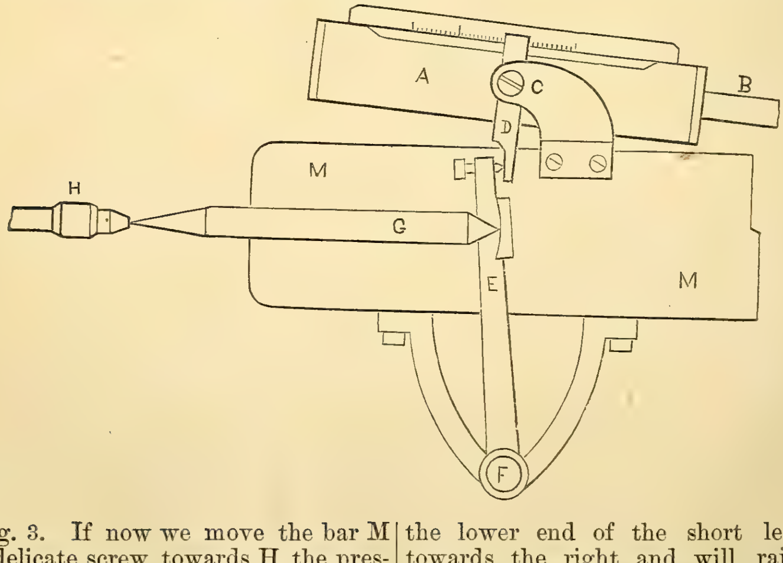


are fastened together at one end, but at all other points are unconnected, except that the upper one rests on the lower by means of little rollers. Thus both bars are free to expand at their own special rates. In Fig. 3 the free ends of the bars are represented by A and B, the upper one being of iron and the lower of brass. The end of a short lever, C, is attached to the lower bar, while the upper bar presses against it at the point D. A movement of the upper end of the lever is communicated to the small rod E, the square point of which is the

end of the apparatus. If now we suppose the bar A to remain stationary while B expands, it is plain that the point of the rod would be drawn back to the position shown in F. If A expanded while B remained still, the point would be pushed ahead to the position G. If both bars expanded equally the whole apparatus would be simply moved ahead. But if the expansion of the two bars is proportioned to the two arms of the lever, the expansion of the upper bar will move the point just as much ahead as the expansion of the lower one will draw it back. The point will thus remain *on the line*, as at H, under all changes of temperature. These two bars are supported from a stiff rib of iron, and very carefully guarded from chance of damage in transportation, the whole being enclosed in a spar shaped covering which serves as a protection from the sun and weather, making in all a shape like that shown in Fig. 4, where one set



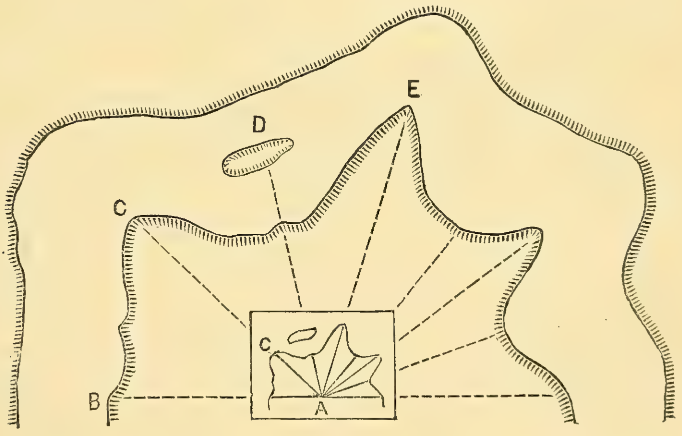
of bars with its covering is seen supported upon two trestles. To measure a base we require two sets of these bars. The back end of the first is brought directly over the starting point and carefully leveled and alligned. The back end of the second is then adjusted exactly to the front end of the first. The first is then carried to the front of the second, the back end of the first being adjusted to the front end of the second, and thus the operation continues, each set of bars being in turn moved to the front. The arrangements by which the two sets of bars are brought not only into exact contact, but always into contact with exactly the same force, is not less ingenious than the contrivance for compensation already described. The principal feature of this device is shown in Fig. 5, though in order to convey the idea clearly we have deviated somewhat from the exact form and have omitted several of the details. A short metallic bar, M M, is attached to the back end of the base apparatus, carrying a small sliding rod, G, terminating with an agate knife edge at the left hand end, while the right hand end bears against a small curved surface attached to the lever, E, turning on a pin at F. The upper end of this lever bears against the short lever, D, turning on the trunnion, C, and carrying the spirit-level, A, which is loaded at one end with the weight, B. H is the forward end of the rod shown



in Fig. 3. If now we move the bar M by a delicate screw towards H, the pressure of G against the lever E will move the lower end of the short lever D towards the right and will raise the weight at B. If we carry this operation

on until the bubble stands in the middle of the level, which may be exactly determined by the finely divided scale on top of the tube, the two rods will be in contact with a certain force. We have thus at each new position of the bars only to bring them together with force sufficient to move the bubble to the middle of the level, and the force of contact will always be the same. This exceedingly simple but effective contrivance may be seen fully illustrated in the Coast Survey report for 1854. So perfect is the above apparatus, and so skillful have the operators become, that after the ground has been prepared and every thing made ready, no less than a mile has frequently been measured in a single day, and with such extreme accuracy that the probable error is estimated to be no more than *the fiftieth of an inch.* At Bodie's Island, in North Carolina, a base line six and three-fourths miles long was measured in ten working days with a total probable error of less than one-tenth of an inch; and the correctness of the supposed error has frequently been proved by the remeasurement of a line. The place selected for a base is one which is quite or nearly level, or one which can without much expense be made so, though the base apparatus is so arranged as to measure equally well upon an incline of as much as three degrees.

The most prominent points along the the coast being accurately fixed by the Primary Triangulation, are used as the starting points for the determination of a secondary series of stations nearer to the shore, and these again for points nearer to the water line, and from the last of these points the shore line itself, and the topography in detail are drawn in by means of the Plane Table, an instrument which though long known had never been so perfected in this country as to be of much service until in the hands of the Coast Survey it has become an appliance well suited to terminate the long series of operations commencing with the Primary Triangulation. The use of this instrument will be well understood by reference to Fig. 6. Suppose that we have the river B C D E, of which it is required to map the shore line. At any convenient point, as A, we place upon the ground a plain rectangular board supported upon a tripod. A sheet of paper is fastened on top of the table,



and on this sheet a point A is marked so as to be directly over the point A on the ground. Next, lay on the table a ruler, one end being placed against the point A, and the other directed to any point on the ground, as B, which it is desired to put upon the map. Draw a line along the edge of the ruler. This line on the paper has the same direction as the real line upon the ground. In the same way direct the ruler to each point in succession the position of which it is desired to fix, and draw the correspondent lines A C, etc. If now we knew the distances from A to each of the points B, C, D, E on the ground, and laid off those dis-

tances by scale on the paper, and through the points thus obtained drew the irregular line, we should evidently have a facsimile of the actual shore line. These distances might, of course, be obtained by measurement, but there is a mode at once more correct and very much more rapid. Instead of a simple ruler we employ a brass bar on which is mounted a telescope, the centre line of which is exactly over, and parallel with, the edge of the bar, so that on looking through the telescope we look much more exactly in the direction of the edge of the ruler than we could otherwise. If we should look through the telescope we should see a fine vertical hair crossing the field of the glass, and also a series of three equi-distant parallel horizontal hairs. If now we should hold up a rod in a vertical position at any distance from the telescope a certain part of that rod would be included between the upper and the lower horizontal hairs. If we moved the rod twice as far off, twice as much of its length would be included by the hairs. This rod is divided into equal parts by figures painted in red and black, so as to be easily read through the telescope at considerable distances. Knowing by trial the number of divisions covered by the hairs for different distances, we tell at once by looking through the telescope, by the number of divisions covered, the distance of the rod from the observer. If now we send an assistant with the rod (telemeter) to each point in succession A, B, C, etc., we know precisely the distances which laid off by scale on the paper enable us to trace the shore line. The great advantage of the Plane Table method is speed and accuracy; for while the rodman is passing from A to B the assistant at the Table is laying off the length of the first line on the paper. By this method all obstacles to chaining are avoided, irregularities in the ground being no impediment, and indeed with two men, one on each side of a river, both shores may be sketched in at the same time to a degree of accuracy and with an amount of detail altogether unknown to the common methods of surveying, to say nothing of the fact that all chances of error in note taking are avoided, and that when the field work is done the plan is also complete; and not only is the outline thus traced, but all of the buildings, land boundaries, and the minutest details of topography are filled in with the utmost perfection, as may be shown by reference to the published charts. Thus, by means of the Primary Triangulation, Secondary Triangulation, and Plane Table, we obtain a minutely exact outline of the coast both in its general form and in its smallest parts, every most insignificant detail being shown exactly on the paper.

The shore line being correctly mapped, we are in condition to commence the hydrographic survey. This consists in making a sufficient number of soundings to show correctly the shape of the bottom, to fix precisely the position of all sunken ledges, bars, reefs, and shoals, to determine the nature of the material, whether rock, sand, gravel, mud, or clay, to detect all currents, the set of the tides, as influenced by the shape of the channels, and all else that can make the route to be followed by ships as plainly known to the sailor as a road upon the land is to a traveler. The exact position of a boat from which a sounding is made is easily found by reference to two fixed points upon the land. The sounding lead is so arranged as to bring up a specimen of the material when it is in any way soft, which, when desirable, is put into a small vial and so registered as to agree with the map. Vast numbers of these vials may be seen in the offices of the Coast Survey, carefully arranged, so that at any future time changes may be detected in the quality of the submarine deposit. Such changes, when closely studied, will point to their origin, and thus to the means of preserving the channel. It is well known that the peninsular of Sandy Hook in 1855 was steadily growing to the northward into the main ship channel into New York Harbor. A spot north of the Hook, where formerly there were forty feet of water, in less than ten years was nearly bare at low tide. Within a century this point has advanced nearly a mile. A careful study of the locality by the Coast Survey has detected the precise movements of the various currents, and shown just how the sediments are deposited, and whence they were derived, and thus pointed out the steps to be taken for maintaining an

open channel. The immense amount of labor expended in the hydrographic part of the survey may be understood by a glance at any of the published charts. The number of soundings thus far made has reached about eight millions. One hundred and forty shoals and reefs and fifty important channels not before known have been discovered, and accurately located, and the position of many hundred isolated rocks and ledges correctly represented upon the charts.

The field work being completed, the work of computing, digesting, and arranging the results, as well as the drawing and engraving, is done in the offices at Washington. And here, too, the Coast Survey has made a most important improvement, viz.—in the application of photography to the reduction of maps, by which the utmost accuracy and fidelity to the original are secured with speed and economy.

The designing and construction of the various instruments have also received a great deal of attention, the result of which may be seen in the splendid work of Wurdemann, which is unsurpassed by that of any maker in the world. Indeed, some of the new patterns of field instruments have been sent to Europe for geodetic purposes, being found better adapted to such work than any others in use.

With regard to the charts, nothing but an examination of these admirable sheets can convey an idea of the amount of labor and skill involved in their preparation. Every natural feature both on land and beneath the water is shown, with the position and description of lights, beacons, buoys, and signals of every kind, the course of the channels and character of the bottom, and minute sailing directions for entering harbors, aided by marginal landscape sketches, showing the general appearance of the shore from different points of approach, all of which can be appreciated only by those whose needs have taught them the value of a sure guide which shall never fail in summer or winter, by day or by night, in sunshine or in storm.

Besides its own special work, the Coast Survey has rendered the most important services to almost every department of science and art. Its discussions of the tides, winds, and ocean currents, its exploration of the Gulf Stream, its observations upon the rise and fall of coast lines, its exhaustive investigations of the complex phenomena of terrestial magnetism, have all served to augment immensely our knowledge of the physics of the globe. Its magnificent triangulation has furnished accurate base lines for state surveys and for geodetic operations in all parts of the country. The Department has also been exceedingly serviceable in supplying a great variety of valuable information to private investigations, to learned institutions, and to officers of public works, and upon proper occasions both men and instruments are freely lent for aiding any scientific operations in any part of the country.

Probably the most remarkable result obtained by the Primary Triangulation, certainly one which shows the extreme accuracy of the work, is the evidence obtained as to the figure of the earth. In order to represent correctly on a map the work done upon the ground, the latitude and longitude of the several points are required. When these latitudes are found by astronomical observation, their position is shown to be not exactly the same as when determined by the geodetic work. These "station errors," as they have been termed, are found after careful examination to arise from the fact that certain irregularities exist both in the figure and in the density of the earth; and wonderful to relate, there appears to be a close connection between the amount of this "station error" and the amount of gelogical disturbance to which the rocks in the different sections have been subjected.

Another most marked advance in science due to the Coast Survey is the electro-magnetic method of determining longitude. The latitude of a place is obtained with comparative ease, but correctly to determine longitude has always been a difficult operation. By the improvements introduced by the Coast Survey longitude is now as accurately determined as latitude, and this new mode, known as "The American method," and which has been introduced and highly approved in Europe, has justly been pronounced "one of the greatest improvements in practical astronomy known to the history of the

science, enabling the observer to do in a given time quadruple the work possible without it with nearly quadruple accuracy."

Among the various instruments, which in the hands of the Coast Survey have been made of especial value, is the zenith telescope. It is justly regarded both on account of its facility for use and the precision of its results as by far the most simple and effective instrument known for the determination of latitude, for which purpose it was first employed by the late Captain Andrew Talcott, of the United States Engineers. More recently it has been also employed for the determination of time. The accuracy of this instrument consists in measuring very small *differences* of zenith distances, instead of *absolute* zenith distances. By means of the micrometer an arc of less than one-twentieth of a second is measured, and the probable error of a single observation is only from three to five-tenths of a second.

The history of this great national undertaking may be thus briefly sketched: In 1806 (singularly enough the very year in which Prof. Bache was born), a survey of the coast was suggested to Mr. Jefferson. In 1807, Congress passed an act authorizing a survey to be made, in which the islands, shoals and places of anchorage within twenty leagues of the shore, with the courses and distances of capes and head lands, were to be represented upon accurately made charts, and Mr. F. R. Hassler, a distinguished man of science, who had been engaged upon the triangulation of the Swiss Canton of Berne, was appointed to superintend the work. In 1811, Mr. Hassler proceeded to Europe to obtain the necessary instruments, but on account of the troubled condition of the country at that time, and for several years afterwards, he did not return until 1816. The following year work was commenced in the neighborhood of New York, but on account of the difficulty of obtaining funds from Congress the work was suspended shortly afterwards, and in 1818 the law authorizing the survey was repealed. From 1819 to 1832, surveys of certain parts of the coast were made by the Navy Department. The results thus obtained, however, were so far from being satisfactory that, in 1828, the Secretary of the Navy pronounced the charts thus made as expensive and unsafe, and recommended a more systematic plan of operation. In 1832 the Coast Survey was therefore commenced anew, and again put in charge of Mr. Hassler, who continued to direct its operation until his death in 1843. Under his management the work was organized, instruments designed and made, assistants trained, and the public made acquainted to some extent with the nature and importance of the undertaking. His triangulation fixed the position of some twelve hundred stations, embracing the coast from Rhode Island to Chesapeake Bay, while the Topography and Hydrography were well advanced. "Mr. Hassler," says one who fully understood his character, "was a man of high attainments and ability, whose scientific management of the work which he had himself initiated had won universal approbation. He had emigrated to this country from Switzerland at the beginning of the century, and had brought with him ideas of scientific accuracy and thoroughness which the public mind in America was not yet sufficiently enlightened to appreciate or even to understand. He gave to the Survey the chief energies of his life, and undeterred by its suspension for fifteen years, resumed its prosecution, when permitted, anew with the same zeal which had marked its inception. On the other hand, he was a man of great eccentricity of manner, and not endowed with administrative ability. At the time of his death, the condition of the Coast Survey was anomalous and Ishmaelitish. Every man's hand was against his neighbor. The Secretary of the Treasury was the real head of the Survey, and the principal assistants reported directly to him and not to Mr. Hassler." In brief, while under a European Government, Mr. Hassler would have been all that was desired for his position, under the Government of this country he lacked just what his successor possessed in so remarkable a degree, wonderful executive power, and the ability of securing the thorough recognition of the importance of the work from Congress and from the people, and of inspiring them with the utmost confidence in his management.

The appointment of Prof. Bache brings

us to the most important and interesting period in the history of the Coast Survey. This eminent man was born in Philadelphia in 1806, being maternally a grandson of Benjamin Franklin. He entered West Point at fifteen years of age, and graduated in 1825, first in a class of extraordinary ability, and what is remarkable, having never in his four years' course received a single demerit. He remained after graduating for a short time as an assistant to Prof. Mahan, and afterwards served as an assistant to Colonel Totten in the construction of Fort Adams at Newport. In 1828 he was appointed Professor of Natural Philosophy in the University of Pennsylvania, at Philadelphia, where he remained seven years. In 1836 he was made President of Girard College, and visited Europe for the purpose of examining the principal educational institutions below the grade of universities, and in 1838 prepared an elaborate report of over six hundred pages, being the result of a thorough examination of two hundred and eighty several schools in Great Britain, France, Switzerland, Holland, Italy, and the German States. The opening of Girard College being so long delayed, he assumed the position of Principal of the High School and Superintendent of Public Schools in Philadelphia, in which position he rendered inestimable services to his native city. In 1842 he was again appointed to his old position in the University of Pennsylvania, which he held until November, 1843, when at the unanimous call of the various colleges, learned societies, and men of science of America, endorsed by such names as Humboldt and Arago in Europe, he was at the age of thirty-seven years appointed Superintendent of the United States Coast Survey, a position for which by natural endowments and extraordinary scientific attainments he was so admirably fitted, and which he retained until his death, which occurred at Newport in 1867.

From this time the work was immensely expanded and driven on with the most untiring activity. In order that the progress might the sooner meet the pressing and rapidly increasing demands of commerce, and that the truest economy might be secured, the coast was divided into eleven different sections, each having as nearly as might be the same length of shore, and each having its own base line, but the whole forming a single system of triangles reaching from Maine to Texas, each division thus verifying the next. By this system, according to the report of the Secretary of Treasury, a double expenditure produced a threefold result, the same parties working in the North during the summer and in the South during the winter.

The extent of the work thus brought into one system may be thus briefly stated:

	Length in miles of general coast line.	Length of the shore line.
Atlantic Coast	3,036	14,723
Gulf Coast	2,162	10,406
Pacific Coast	1,866	4,252
	7,064	29,381

If we suppose the whole time necessary for the completion of the work to extend from 1840 to 1880, or forty years, and the annual expense to be five hundred thousand dollars, we shall have paid for our whole thirty thousand miles of shore line twenty millions of dollars, a sum greatly less than any other government has paid for the like amount of work. It has been stated, and correctly, that the annual cost of the Coast Survey never exceeded the cost of a first-class steamer. Certainly the whole cost from the commencement has not surpassed the value of a dozen first-class Indiaman with their cargoes.

"The rule of Professor Bache in the work of the Coast Survey," says his memorialist, "was that all of the scientific work should be executed in the most thorough and accurate manner which the resources of science and art would permit. He never shunned a tenfold labor if it was to be repaid by a double precision, accepting the great principle which prescribes a higher rate of effort as we climb to higher degrees of refinement." Under his guidance for twenty-four years the best scientific talent of the country was drawn into the service of the Coast Survey. The nineteen quarto volumes of the Coast Survey Reports from 1852 to 1870, containing no less than six thousand pages and eight hundred plates, besides one hundred and twenty-three scientific papers presented to different associations

from 1829 to 1864, with his annual reports as Superintendent of Weights and Measures, and twenty-one several reports upon various harbors, the last made jointly with Messrs. Davis and Totten, all testify to the immense activity of the man. Not the least laborious part of his work, but certainly the least agreeable, was the perpetual exertion necessary to counteract the attempts of evil-minded people at Washington. Hardly a session of Congress passed in which personal spite, local jealousy, prejudice, or envy, did not show its hundred-headed "bad-visaged front," striving always to sap the foundations of the noble structure which was steadily rising to the public view, until at last so virulent were these attacks and so apparent their animus that the learned societies, chambers of trade and commerce, insurance companies, and private individuals, all over the country united in one grand protest against interference.

The opinions of European savans in regard to the Coast Survey and its director, may be gathered from very numerous letters from such men as Arago, Humboldt, Admiral Smyth, and, lastly, from Sir Roderick Murchison, who in presenting the Victoria Gold Medal of the Royal Geographical Society of London, to Prof. Bache, remarks, that whether we regard the scientific skill and zeal of the operators, the perfection of the instruments, or the able manner in which the Superintendent has enlisted all modern improvements into his service, all must agree that the Trigonometrical Survey of the United States stands without a superior."

When it is considered that the Coast Survey organization embraces not only civilians, but at the same time officers of both Army and Navy, it will be seen that the chief who could so direct these somewhat discordant elements as to produce a maximum of progress with a minimum of internal dissatisfaction must be no ordinary man. We may, therefore, well understand and believe the truth contained in the following eulogistic words of his memorialist:

"It was not merely by his ardent love of science, and his disinterested devotion to her welfare that he accomplished so much. His fertility of device, unconquerable assiduity, large policy, generous impulses, patriotic devotion, might well have co-existed without yielding such fruits in the development of the Coast Survey, or such a mighty power for good in the promotion of science throughout the United States. More was needed than these; far more than these he possessed. The greatest of all his mental gifts, or attainments, were his marvelous knowledge of human nature and his unrivaled skill in using it. He had studied men as he would study physical phenomena. To a faculty of persuading the most obstinate, of soothing the most irritable, of encouraging the most disheartened; to a power of stimulating the most indolent, controlling the impulsive, winning over opponents by the charm of his manner, and confirming friends by the truthfulness and sincerity of his nature, he added that rare endowment, which imbued others unconsciously with his own zeal. His companionship evoked latent aspirations, and pointed to noble aims. He knew the secret of obtaining work from his subordinates, by doing more than they did. By no act of his life did he ever curtail any man's means of usefulness, or fail, whenever it was within his power, to render available whatever abilities might be disclosed. Justice and even-handed firmness controlled his action. Cautious in plan, bold in action, as courteous to his assistants and as considerate of his subordinates as though they had been his superiors, ever as open to conviction as to argument—such was his noble character. The progress of education, the development of scientific research, the extent of scientific discovery, the growth of the arts and the spread of commerce have all been greater in America because he has lived."

It is almost impossible to do justice to the chief of an important undertaking without doing a seeming injustice to his associates and assistants. Many of Napoleon's Marshals were great men, but Napoleon's greatness overshadowed them all. Great as Prof. Bache was, he never could have accomplished the vast work of the Coast Survey unaided. Without the labor of his assistants—most of whom are yet active workers in the field—the admirable results which we now see would never have been reached, nor should we have had the declaration from one of England's foremost men of sci-

ence, that "The Coast Survey of the United States is one of the most perfect exemplifications of applied science of modern times."

DOMESTIC MOTORS.

From "The Engineer."

Let it not be thought that the subject dealt with in this article is too insignificant to deserve the attention of mechanical engineers; nothing which can add to the comfort of a civilized community is too trifling to claim the exercise of the talent for invention. Who will supply a want long felt, and give the world a really good domestic motor, an engine of some kind which will drive any or all of the machines now common in almost every household? At first sight it would appear that there can be no great difficulty in producing a small apparatus which would suffice to drive a sewing machine, a knife cleaner, or a washing machine; but a little examination of the subject will show that it is rather more complex than appears at first sight. Attempts have been made to solve the problem, but we question if those who have made these attempts have gone quite the right way to work. As the conditions are not easy of fulfillment, we shall first state these conditions, and then indicate the direction which inventors should take to satisfy them. In the first place, then, a domestic motor must be safe—that is, it must be absolutely free from risk of explosion or fire. In the second place, it must be generally applicable. In the third, it must not be likely to get out of order. Fourthly, it must be perfectly under control, and require no special skill to manage it. Fifthly, it must be cleanly in its operation; and lastly, it must be cheap. One or two minor requirements might be stated, but we believe we have enumerated all that are essential. It is obvious that what applies to the production of motive power in the abstract will apply to all motive power engines, small or great. We cannot create power, and so, whether we want to propel an ocean steamship or to drive a sewing machine, we must call in some of the forces of nature to aid us. Before going further, therefore, we may at once dismiss all such schemes as the winding up of springs or weights to produce motion. The power to be thus obtained must first be got by the exercise of manual labor, and it would be better to apply this labor directly to the machine to be driven than indirectly to springs or weights, for reasons very well understood by engineers, at all events. The forces of nature available for our purpose are gravity, heat and electricity. They can be applied in various ways as follows: Firstly, gravity is available under certain conditions in the fall of a body of water; heat can be utilized by a steam, hot air, or gas engine; and electricity can be made to serve our purpose by the aid of the magnet. From this list our domestic motor must be selected. It remains to be considered which is most like to serve our purpose.

Where a constant supply of water under pressure is available, it would seem that nothing is so suitable for driving a domestic motor. It is not beyond the skill of the engineer to construct a little turbine, for example, which could be fixed in a neat case against, or even sunk into, the wall of a drawing-room, and to which a pipe, concealed like a gas pipe, behind the wall-paper, could be laid from the cistern on top of the house, while the discharge pipe could, similarly concealed, be led to the most convenient place where it might be discharged into a drain. The space occupied by a little turbine of this kind would be quite insignificant. The covering might be rendered very ornamental, and the power could be taken off by a small belt or gut line. In this way every drawing-room or boudoir might contain a motor available at any time to drive a sewing machine. Its operation would be quite silent, danger there would be none, and to start or stop it would be as simple an operation as turning gas on or off. If necessary, the same plan might be carried out to drive a washing machine,

knife cleaner, &c., in the basement of a house, a somewhat larger and coarser machine being used. But in no case would the turbine take up much room or use a great deal of water—about one-fifth of a horse-power is the maximum that would be required. This would be obtained by the expenditure of about 2,000 gallons of water per hour under a head of 20 feet, or half that quantity under a head of 40 feet. This would practically represent the work of a couple of strong men. To drive a sewing machine, of course very much less would suffice. Where water under a sufficient head is available in the requisite volume nothing better than the arrangement we have sketched out can be desired. It is evident, however, that in London, at all events, and indeed in most large cities, water cannot be had in this way in sufficient quantities, and we must reluctantly reject the turbine as not fulfilling all the requirements of an almost universally applicable domestic motor.

Steam may be used for the required purpose, and an apparently not unsuccessful attempt is now being made by a London firm to introduce miniature steam engines for driving sewing machines. The little engines are on the oscillating principle, are extremely simple, and well made. Steam is supplied by little vertical boilers, heated by a Bunsen burner or ring. No chimney is required, and the exhaust steam is carried off by india-rubber pipes. Although the pressure used is low and the boilers small, the arrangement cannot be pronounced quite free from danger; and the heat and smell inseparable from the use of steam, and the difficulty of satisfactorily disposing of the exhaust, must always tell against the popularity of this, or any other form of steam engine, as a motor suitable for drawing-room use, although it would, no doubt, prove serviceable in tailoring establishments, and other places where a considerable number of sewing machines have to be worked; and it would probably do good service in small laundries. It will be seen, then, that neither water nor steam is likely to supply what we want. We may take electricity out of its order, to dismiss it at once, as being too costly, delicate, and troublesome to satisfy our requirements. Nothing is left, then, as likely to furnish motive power, but hot-air engines, gas engines, or petroleum engines. Hitherto hot-air engines have not been successful; but this is due to causes which would hardly operate in the case which we are considering. It ought to be possible to produce a little hot-air engine which would drive a sewing machine silently and without trouble, the heat being supplied by a gas jet. The little engine need not weigh more than a few pounds; economy would not be sought, and the regenerator could be wholly left out. The gas could be taken from the gaselier overhead by an india-rubber tube, and as it would not be necessary to wait for a fire to burn up, the machine should be ready to operate in five minutes after the gas was lit. There would be little that was objectionable about the machine. It would be perfectly safe, easily managed, and the hot air discharged would be small in quantity, and readily disposed of by the ordinary ventilation of the apartment. Larger machines, but still small, could be used for heavier domestic work. We are disposed to regard the hot-air engine as presenting an excellent solution of the problem; but something still better may, perhaps, be found in the gas engine. Lenoir's engine, apart from the electrical apparatus, which is not essential, we need hardly say, was simple enough, and we see no difficulty in constructiug little engines on this principle modified, of, say, one-tenth of a horse-power, which might be elegant in design, simple, and easily managed. Petroleum engines the world knows too little about at present to enable us to present any opinion on their suitability for the required purpose; but while gas is available, as it now is, in every town and in many country houses, we see no reason for abandoning it in favor of petroleum.

One point remains to be dealt with, namely, the cost of a domestic motor; this must be small. It should not much exceed £5, if a large sale is expected, and we venture to think that the very magnitude of the sale which would be secured for a really satisfactory domestic motor would enable the price to be kept within the limits we have named. It may be argued that to produce an efficient motor, however small, for £5 is

absurd, but we cannot agree to this. A steam engine, for example, is by no means so complex as a sewing machine, but the latter can be sold for £5, allowing a good margin for profit. Not many years since we heard it argued that it was impossible to produce a lawn mower, which would be of use, for less than £5. Excellent little lawn mowers are now sold literally by the thousand for 25s. If a good design is once obtained every portion of the domestic motor might be turned out by machinery, and fitting reduced to a minimum. No engineer, it would seem, really knows what he can do till he tries, and we are certain that by trying, not only may a motor be supplied, but that it can be sold, if not for £5, for something very near that sum.

Whether a sufficient demand would exist to make it worth while to invest capital in the requisite plant for turning out domestic motors by the thousand, is a question which we cannot answer decidedly, nor can anyone else. If we reason by analogy, it would appear that the same laws would apply to such machines as to several others. The first man who made portable engines gave up the business after he had turned out twelve, because, he argued, that more than a dozen portable engines could not possibly be wanted in England. When the sewing machine was first produced it was held that the demand for it must always be limited. Sewing machines are now made by the million. We might cite a great many other instances to prove that the possibility of obtaining a given machine appears to create a demand for it, and we think this would apply in the case of the little engines with which we are dealing. However, it is perhaps premature to speak of the possible demand for a machine which does not as yet exist; although we have no doubt that it is practicable to produce it, some exercise of inventive ability will be needed in the production.

NAVAL GREAT GUNS AND GUNNERY.

From "Iron."

A PAPER on this subject was read recently by Mr. J. Scott Russell at the Royal United Service Institution. Mr. Russell said: "What I propose to lay before you to-night is the special question—What should be our new navel gun, to take the place of my favorite old 8-inch guns? The two important points I first want you to settle are these: What weight of gun can you accept as the (handleable weight) manageable weight of gun? Next, what work do you want the gun and its projectile to do? If you settle these two leading points, I think I can see how all the rest can be done. To secure most execution at moderate and sure range seems to me the essential character of naval gunnery as distinguished from land gunnery. If that be agreed, I now proceed to see how we can get most use for that end out of our 12-ton gun. I say then at once that you will get much more practical good out of your 12-ton gun by giving it a large bore of 12 inches than a smaller bore of 8½ inches. In a 12-inch bore the powder-power propelling the shot is 144. In an 8½-inch bore the propelling power is 72. Or the work done by the 12-inch bore is double the 8½-inch bore. For the present I confine myself to this statement; I will prove it later on. Next, I will take the question, how shall we turn this double propelling question to account? We have two ways, to send out a heavier shot, or to send out the same shot with higher speed. Now, in regard to weight of shot, I may observe that as you have fixed weight of gun I shall consider the weight of shot as fixed also. Your gun weighs 12 tons, that is, 240 cwt. Now, according to the best practice in all countries, the normal shot is 1 lb. of shot to each 112 lb. of gun. This gives for the 12-ton gun 240, or 12-ton gun (240 cwt.) 240 lb. shot. Taking, then, 240 lb. shot in 8½-inch gun, and 240 lb. shot in 12-inch gun, we have double the powder-power propelling the same shot; or double the propelling force pushing forward the base of the shot. Therefore, the same weight of shot will be discharged with much higher speed. Now speed of shot is, as you know, a much more effectual means of destruction and penetration than mere weight; double weight of shot has double pene-

trating power; double speed of shot has fourfold penetrating power. The larger bore has, therefore, the great advantage of giving higher speed of shot and greater penetrating power. Double weight gives double destruction. Double speed gives fourfold destruction. The next element of efficiency is the power of the hollow shot as an explosive shell. I need not prove that with the same weight of piercing shell, the larger bore admits of much larger explosive effect of the shell. Shell has much larger capacity for explosive charge. Thus, then, in all these ways greater initial speed, greater destroying power, greater explosive effect, the large bore 12-ton gun is more effectual for naval use than the smaller bore. So much for the power of the larger gun for more work. I now proceed to show how, by wise arrangement, this larger bore gun of 12 tons may have more endurance than the small bore gun also of 12 tons. I shall be told at once that it is quite true that my large bore has greater propelling power on the shot than my small bore; but that the powder in my large bore has greater bursting power on the gun barrel than in the small bore. This is quite true, but it is true in quite different proportions. The propelling power is as 72 to 144. The bursting power is as 102 to 144.

This gives a clear balance in favor of the large bore of 144 to 102, or of 42 per cent. gain. Propelling powers 72 to 144. Bursting powers 102 to 144. The larger bore is the more lasting gun. Thinner metal, 21 to 24; more effective distribution, 26 to 18; gain, 54 to 43. The next question is mode of rifling. On this I have merely to say that I have always been the consistent advocate of accelerating twist for small bore guns with common powder charges. But for large guns with new and well-regulated powder charge, I am of the opposite opinion. For large guns, with regulated powder charge, we must lay aside accelerating twist and come to uniform twist. My reasons are two. First, accelerating twist injures large guns; second, it is rendered quite unnecessary with a regulated powder charge. What we want is not slow burning powder, nor quick burning powder; but powder-charges that will burn quick when we want it quick, and slow when we want it slow. Or what I call a regulated charge, slow burning of powder at first, gradually growing quicker and quickest at last. Now, if you can get that done, your guns will last longer than they have ever done, your shot will go further, and faster, and steadier than they have ever done, and your whole work will be better done than ever. We now meet face to face the next question, Have we got such regulated powder charge as I speak of? The answer is, No, very much the reverse; and then the next question, Can we get them? I answer, "Say you wish it," and you will get it. As to the material of which our naval gun should be made, there need now be no doubt. Steel and iron can now be made of any required quality, and nearly any quantity in one piece I know that the 12-ton 12-inch gun we have been discussing can be made of Whitworth's condensed tough, powerful steel, in two concentric tubes or cylinders, an outer and an inner tube. I dare say that our engineers at Woolwich will be able to make you the outer body of that gun in one piece of wrought iron, with an inner single tube of Frith's steel. By and by, if you desire it, the gun may be one whole, but at present I prefer to have it in two layers, outer and inner, but each extending the whole length, and not in patches. Cheaper shells might be good enough for practice, but I consider that when you come within shot range of your enemy, there is no shell, however costly, that should be reckoned "too good" for him. In short, the most effective would be really the cheapest. In regard to gunnery and gun carriages, I think that when you have resolved to adopt breech-loading matters are simplified very much. I think the existing naval gun-carriage, as designed by Captain Scott, is an extremely good one. I also am of opinion that for certain special ships of war the gun-carriage of Major Moncrieff offers very important advantages in use, and facilities in application. But the most important of all gun carriages is the ship herself, which carries the great guns we are now discussing. Unless the ship herself possesses all the qualities of a handy, quick, steady, secure gun-carriage, nothing we can put on board of her will enable her to win a battle at sea.

RECLAMATION OF THE SUBMERSIBLE LANDS OF THE MISSISSIPPI VALLEY.

By J. P. FRIZELL.

Written for Van Nostrand's Engineering Magazine.

By an Act of Congress, approved June 22, 1874, the President of the United States was authorized and directed to appoint a Commission "To make a full report to the President of the best system for the permanent reclamation and redemption of said alluvial basin from inundation."

The Commission consisted of three engineer officers, viz.:

Major G. R. Warren.
Major H. L. Abbott.
Captain W. H. H. Benyaurd.

And two civil engineers "eminent in their profession," viz.:

Jackson E. Sickels; and
P. O. Hébert.

This Commission presented a report under date of January 22, 1875, in which they advert to the several methods of protection that have at different times occupied the public attention, and indicate the following as their conclusions:

The attempt to control the height of floods by cut-offs is fraught with such danger to the banks that it should never be made; then spontaneous occurrence should even be prevented when practicable.

Division of tributaries is not thought worthy of serious consideration.

The Commission summarily condemns the project of a system of reservoirs as "chimerical.

"The "Commission is forced unwillingly to the conclusion that no assistance in reclaiming the alluvial region from overflow can judiciously be anticipated from artificial outlets. They are correct in theory, but no advantageous sites for their construction exist."

After considering some objections urged against a completed system of levees, and pronouncing them unfounded, they proceed to recommend this mode of protection. The report goes on to prescribe the height of levees for different parts of the river, with reference to the highest known flood occurring in the uncompleted state of the levees, viz.: 3 feet near the mouth of the Ohio, increasing to 7 feet at Osceola; thence to Helena this latter height should be maintained; thence to Island 71 gradually increasing to 10 feet, gradually diminishing to 8 feet at Napoleon; thence to Lake Providence it must be gradually increased to 11 feet; thence to the mouth of the Yazoo it must be gradually reduced to 6 feet, and it should thus be maintained to Natches; thence to Red River Landing it must be gradually increased to 7 feet; thence to Baton Rouge it may be gradually reduced to 5 feet; thence to Donaldsonville this height must be maintained. At Canolton, 4.7 feet will suffice, &c. The levees should be located at a sufficient distance from the river bank to guard against caving. An approximate estimate is presented of the cost of a completed system amounting to about 45 millions of dollars.

Upon completion of the works they propose to intrust their maintenance and care to a board of engineers or superintendents, each of whom will exercise authority in a certain district, and who will have a mutual organization with powers and functions analogous to those of the river syndicates of France and Spain. They recommend further an accurate instrumental survey of the entire alluvial region subject to overflow. It is very much to be regretted that this survey was not authorized by Congress.

Without denying the general conclusions of this Commission, I must be permitted to say that they would, in my opinion, have been entitled to more weight had the report more fully met certain grave objections to which a completed levee system is liable.

What is said of the tendency of dyked rivers to elevate their beds, is substantially a repetition of the views contained in Humphrey's and Abbott's report. It appears to me that the true source of danger is not discussed in either of these

reports. We need not ascribe to rivers dyked or undyked any tendency to elevate their bottoms or their low water surfaces. It is none the less true that a completed system of dykes does set in motion causes tending inevitably to the progressive contraction of the high water section of the river, and the progressive elevation of its flood surface.

That the deposits resulting from the overflows of the Mississippi, in its natural state, have elevated the ground in its immediate vicinity, is evident from the fact that the ground, in all cases, descends as you recede from the river; the river banks being often 10 or 15 feet higher than the swamps which lie parallel with, and at some distance from, the river. Upon the completion of the system of dykes, it is equally evident that this process must cease inside the dyke, while continuing with increased vigor outside. The exposed ground (*vorland* as it is called in Germany) is withdrawn from cultivation. Every overflow is succeeded by a rank growth of bushes and reeds whose roots hold fast the material deposited, and whose stems operate to check the water and increase the deposits of the next year. The evil is greatly aggravated if the *vorland* is protected by a low dyke as suggested in the report. In this case, at every overflow of the low dyke, the *vorland* is filled with turbid water moving with a very moderate velocity, a condition favorable to enormous deposits. I have seen, on the Mississippi, in the analogous case of a flooded coffer dam, a deposit of more than 12 inches in the course of a single flood.

The contraction of the flood water way, from these causes, tends, of course, to increase the height of the floods, and levees originally sufficiently high will require to be progressively raised and strengthened.

In swampy regions, another cause comes into operation to increase the height of floods with reference to the reclaimed ground, *i. e.* the subsidence of the latter in consequence of the better drainage permitted by the levees. Reclaimed polders in Holland usually sink one or two feet from this cause.

It is not alone with reference to the Po, as the report appears to assume, that apprehensions of gradual elevation have been entertained. Such fears have been felt with reference to the Rhine, and this not alone by speculative physicists, but by engineers specially conversant with this branch of their profession.

Hagen* considers the fact of such progressive elevation well established. He cites two papers bearing upon this point. One, a memoir presented by Blanken† to the Institute of the Netherlands in 1818, in which he shows that dyke-breaks upon the Rhine and Waal had increased in frequency, as compared with the preceding century, notwithstanding the raising and strengthening of those dykes which were then much higher than formerly. The other, a report by Rechtereu,‡ in 1830, in which he goes so far as to recommend the flooding of the country in the winter as the only means of avoiding ultimate ruin.

The Commissioners say: "The prolongation of the delta into the gulf by the aggregation of sedimentary matter is also assigned as a cause for the ultimate rise of the bed, and hence for a future necessary increase in the height of the levees. A possible secular change of this nature is quite too remote in its effects to merit attention from practical men of the present day. Simple calculation will show that hundreds of years will be required to raise the flood height at New Orleans an inch from this cause."

Here, again, it appears to me that the Commissioners have failed to note the real danger to be apprehended from changes at the mouth of the river. A passage in the physical history of the lower Rhine may be interesting in this connection. I translate from Hagen:§

"At what time the old Rhine was entirely closed, and when the numerous connections between the Waal and the Maas, either spontaneously originated or were artificially opened, is unknown. Many dyke-projects, however, were executed in the twelfth and thirteenth centuries at which time the entire existing dyke-system originated. Whether this was done in the immediate interest of agriculture, without reference to its ef-

* Handbuch der Wassenbankunst. Theil 2 Band. 3, p. 704.

† Beschouwingover de Uitsrooming der Opper Rijn en Maas-Wateren. Amsterdam, 1819.

‡ Verhandelingen over den Staat van den Rijn, de Waal, etc. Nijmegen, 1830.

§ Handb. d. Wassenbankunst. Theil 2 B. p. 428.

fect upon the regimen of the rivers, cannot now be ascertained. Certain it is that the dykes became a new cause of derangement to the rivers, and many new channels were opened by dyke-breaks. The most frightful instance of this kind was the overflow of the Waal and Maas in the South Holland Waard, or the *Bergsche Feld.* The Maas had already, in the lower part of its course, united itself with the Waal, and both, on the 18th of November, 1421, broke through the left dyke, between Woudrichem and Dortrecht, and flooding the low lands, destroyed a surface of many square* miles. The water thereby opened for itself a new mouth in the sea, through the deep and wide bay of the Beisbosch, through the Holland's deep, and through the Krammer. Seventy-two† villages were destroyed by the water together with the ground on which they stood. This devastation is only explainable upon the supposition that the sea, being put in communication with the dyked land, entered it at every flood and receded at every ebb. Thus originated the powerful currents which led to the widening and deepening of the channel. A natural consequence of this dyke-break was that the Waal now took the level of the North Sea at the Beisbosch, that is, 10 miles (about 45 English miles) from its former mouth, and its course was, thereafter, shortened by that distance. The relative fall thereby augmented, as far as the point of separation (from the Rhine), at Lobit. The rush of waters increased, and in proportion as the channel was extended and deepened, those of the Rhine, the Leck and the Issel were shoaled by the diminished velocity. This relation which promised the entire closing of the weaker arms and the ultimate reunion of the streams in a single channel, disappeared, however, and a remarkable change was allowed to develop itself in the course of some centuries. The Beisbosch was, by the sediment of the river, and possibly also by tidal action, gradually filled up, and the broad bay was replaced by a marshy region in which isolated islands already raised themselves above the ordinary level of the water. They were overgrown with grass and bushes, and were soon provided with dykes. Between them were a great number of shallow water courses, which were naturally no longer in a condition to carry off the greater part of the volume of the Rhine, and still less could the level of the sea establish itself therein. The low water-level in the Waal thus disappeared, and with it the former large (relative) fall. The Rhine and the Leck, and likewise the Merwede or lower part of the Waal, thereupon took a stronger current, and the entire volume of the Rhine resumed its course through these arms, while, in consequence of the previous diminished current, the depth therein had diminished in a remarkable degree, and they had become entirely insufficient for carrying off the waters. The streams could only be confined to their beds by raising the dykes, but they filled these to such an alarming height that not only did the natural drainage in great part fail, but the danger of dyke-breaks ever increased and the existence of many important places was continually threatened."

We see, then, that apprehensions founded upon possible changes at the mouth of the river are not so groundless as the Commissioners suppose. The completion of a system of dykes is very liable to cause changes in the course of the lower river by curasses, and these changes are liable to necessitate an increase in the height of the dykes.

I pass now to another point of most vital importance, which, strange to say, has not been touched upon, either in this report or in the very voluminous and valuable report of Humphrey's and Abbott. How is it proposed to deal with the rainfall in the reclaimed district?

In the history of the levees, thus far, this question has attained no practical significance. They have been built to meet immediate and local wants, with but slight consideration of ultimate effects consequent upon the completion of the system. They have afforded protection only to the higher grounds near the river, leaving always extensive swamps in the rear to receive and convey away their surface water. Upon the completion of the system, the swamps above Red River will no longer afford this relief. Their outlets are liable to be back-

* A square German mile is about twenty square English miles.

† Blanken. Memorie betrekkelligk den Staat der Rivieren. Utrecht, 1823, page 22.

ed up from four to ten feet above the highest flood hitherto known. The flood stage of the river lasts sometimes three or more months, during which time the alluvial districts are liable to receive a rainfall of two feet or more. Without efficient drainage, their condition will hardly be improved by the levees. In fact, extensive tracts will be liable to overflow several feet deep, which, without levees, would have been above water. Claims for protection will be urged with redoubled vehemence, claims which the Government cannot in justice disregard, the evils being of its own creation. I can conceive of no effectual remedy for these evils other than a vast establishment of steam-pumping machinery. Such an establishment is ultimately inseparable from a perfected system of levees. If the Government commits itself to the first, it cannot reasonably or justly evade the second.

Let the reader endeavor to form an idea of the cost of such an establishment, capable, for instance, of relieving a district 20,000 square miles in extent, of 12 inches of rain-water in the course of 30 days, the water to be raised 12 feet. The result is absolutely appalling. More than three times the sum assigned as the entire cost of the levees.

It is not the purpose of this communication to offer anything in the way of practical suggestion, but rather to urge the importance of a more thorough consideration of the subject than it appears to have received from this Commission. The method of protection by levees, once resolved on and undertaken by the Government, must be persevered in, however great the difficulties in their maintenance developed by time. The longer they afford protection to the country, the more important become the interests to be protected, the more deplorable results of failure, and the stronger the obligation to maintain the system. The Government should not be committed to action so momentous and irrevocable without all the light that the history of similar works can afford, lest the difficulties, now but dimly to be foreseen, should progressively acquire such strength as to become utterly overwhelming.

LIME.

From "The Builder."

Of all the materials used in construction, lime is perhaps the most important, and the following *resumé* of several series of experiments made by French engineers and others into its nature and treatment cannot fail to be acceptable.

I. *Pure or quick Lime, Oxide of Calcium*, is composed of 28.58 parts of oxygen, and 71.42 parts of calcium, a substance white in color, caustic, pulverulent, absolutely infusible in the fiercest fire, susceptible of crystallization in rhomboidal prisms, and of a burning and acrid taste; it quickly disorganizes animal substances brought into contact with it, turns syrups of violets green, and gives to turnsole the same reddish blue color as an acid.

Its specific gravity is 2.30. It dissolves in 900 or 1,000 times its weight of cold water, or in twice that quantity of boiling water. It is scarcely ever found in nature in a state of purity, except in some volcanic productions.

Brought into contact with water, it is transformed into hydrate; it gives out a quantity of heat which may amount to 300° centigrade, and is capable of igniting gunpowder; a part of the water escapes in the form of very hot vapor, slightly caustic, and a noise is produced resembling that caused by plunging red-hot iron into water; it melts or is reduced into impalpable powder, or into paste. This hydrate is *chaux amortie*, *chaux coulée*, or *chaux éteinte*, slaked lime, to distinguish it from quick or anhydrous lime.

II. *Physical Characteristics.*—When slaked, lime increases in volume; it swells according to its degree of purity, and sometimes attains a volume two or three times that of the quicklime from which it is produced. That which has

absorbed a volume of water equal to 2.60 to 3.60 for one of lime is called *chaux grasse*, or fat lime; and which has only taken up 1 to 2.30 per cent. of water, *chaux maigre.* When the latter hardens, not only in the air but under water, it is called hydraulic lime.

III. *Limestone.*—Lime is obtained for industrial purposes by the calcination of calcareous stone, a substance composed of lime and carbonic acid, and which partly dissolves in weak acid, with more or less effervescence. The quantity of lime which it is capable of yielding is in proportion to the carbonate of lime contained within it.

Pure carbonate of lime is very rare; it contains 55.98 parts of lime, and 44.02 of carbonic acid. When calcined at a high temperature, it yields pure caustic lime.

Calcareous matter is one of the most common. In nature, it is usually mixed with silica, alumina, magnesia, quartz in grains, or sand, clay, oxide of iron, manganese, bitumen, and sulphur, or pyrites. The combination of these various substances constitutes several kinds of limestone, which are subdivided into many varieties.

Mineralogists distinguish several kinds of limestone, and point out varieties of form and texture in each; but that which is important for the builder to know is, that each kind furnishes a special line different in color, density, greediness for water, and especially in its practical results when mixed with sand.

The physical characteristics of calcareous stones furnish no certain data with respect to the kind of lime they will yield, and even chemical analysis affords but approximate results. Formerly it was maintained that the hardest, heaviest, most compact, and most homogeneous stones, with the finest grain, made the best lime; it is now admitted that these characteristics are not sufficient indices of the quality of the products to be obtained from them. It is only by trials and experiments that their value can be determined. The purer the limestone, the more the lime obtained will swell; if the carbonate of lime contain foreign matter to the extent of ten or twenty per cent., the lime after being slaked will swell very little or not at all, it is poor.

IV. *Hydraulic Limestone.* — As hydraulic limestone is the most valuable on account of its peculiarity of hardening rapidly under water, it is most important to ascertain what limestone will furnish it. For a long period scientific men were not agreed as to the causes which rendered lime more or less hydraulic; some attributed this peculiar property to the presence of metallic oxides, others to a combination of silica and alumina. Smeaton, in 1756, discovered that the hardening by immersion was due to a certain quantity of clay contained in the limestone possessing that quality. MM. de Saussure, General Freussard, Berthier, and Fuchs, of Munich, have published remarkable papers on this subject, but no one has done so much for it from a scientific point of view as M. Vicat. Before his time there were not ten quarries in France in which hydraulic limestone was known to exist, but after traveling the country on foot for years, he discovered more than three hundred, and there is not a department in all France that does not owe to him the discovery of a mass of mineralogical wealth.

V. *How to recognize hydraulic Limestone.*—Hydraulic lime being produced from the mixture of carbonate of lime with clays, it is important to know the quarries in which the variety is to be found. M. Vicat recommends that the strata should be deeply sounded, as the chemical composition of the lower layers may differ sensibly from that of the layers more exposed to the influence of the atmosphere. It has been remarked in general, that limestone of a dirty grey, ashy, or bluish tint, contains much more of the argillaceous or silicious principles than that of a compact or crystalline texture. The information obtained from miners and masons is very useful; and we must not be disconcerted by failures; they arise, generally, simply from misdirection of research. M. Chateau relates that for a long time Paris obtained her hydraulic lime from Senonches, at the cost of 80 francs the cubic mètre, while the quarries of the Buttes - Montmartre, the Buttes-Chau-

mont, and Romainville, which yield limestone that produces all the varieties of hydraulic lime, remained unexplored. For the testing of limestone, M. Vicat recommends the burning first of a small quantity, and afterwards on a large scale. The difference of the weight and the value of the products will thus set all doubt at rest.

VI. *Mode of Trial.*—The method proposed by Mr. Berthier is as follows:

Crush the limestone, pass the powder through a silk-sieve and pour upon it little by little muriatic acid, or, in the absence of that, sulphuric acid, or vinegar, diluted with a small quantity of water, stirring it continually with a glass rod or a stick, and continuing the application of the acid until all effervescence ceases; evaporate the mixture with a gentle heat, and when all is reduced to a soft paste mix this up with about a pint of water and filter it; the clay, which will remain on the filter, must then be dried, either in the sun or before the fire, and weighed; or, which is better, calcine the clay to redness in an earthen or metal crucible before weighing it, then pour lime-water on the filtered solution so long as any precipitate continues to fall; collect this precipitate, which is magnesia, sometimes mixed with iron and manganese, as quickly as possible on a filter, wash it with pure water, dry it as completely as possible, and, finally, weigh it. The weight of the clay compared with that of the calcareous substance dissolved gives approximatively the rank which the mineral should fill amongst hydraulic limestones. It is important to note that after the first filtration no clay may be found, or only a mixture of fine sand with clay; in the former case, the limestone will only furnish poor lime; in the latter, the sand must be separated from the clay by washing and decantation, to ascertain the respective weight of each.

VII. *Lime-burning.*—In the burning of lime, all kinds of fuel are employed, according to the locality—wood, heather, peat, coal; coke gives excellent results, charcoal not so good, besides being very dear. The form of the kilns varies with the customs of the place, and the kind of fuel employed: it should tend to economize the latter, but without endangering the quality of the product. In those regions where wood is abundant, the kiln is often a simple square or circular excavation, about 6 ft. wide by 10 ft. to 11 ft. in height, the interior being lined with dry stones, or, still better, fire-clay bricks. The limestone is thrown in, but not too compactly, so that the flame may circulate, and the smoke escape; the fuel is then placed in a space left in the upper part of the mass. No arrangement whatever is made to concentrate the heat, the loss of which is enormous, and the burning of the limestone is unequal.

The forms employed for better constructed kilns are the right-angled prism, the cylinder, the cylinder surmounted by a truncated cone, the reversed truncated cone, and the ellipsoid ovoide, with variations. The rectangular forms are used in the centre, south and east of France. Bricks and lime are burned in them at the same time. The limestone is placed below, filling up half the kiln, and the upper part is filled with bricks or tiles. When a large quantity of lime is required rapidly, the cylindrical form is employed; their construction is economical and easy, but they do not last long. The limestone is built up like a tower, and covered with beaten earth, the fire being introduced below.

The other kilns are built in a solid and durable manner; no bricks are burnt in them; the large stones are placed below, and the small upon them in the upper cone. The ellipsoidal and ovoidal kilns are for burning by means of coal or coke; their linings are of brick, 16 in. to 20 in. in thickness, set in mortar made of refractory clay and sand.

In the long-flame kilns, fed by wood and heather, the charge rests on one or two arches constructed of the same materials as the kiln; the fire increases with the draught, the mouth is kept filled with fuel, the flame makes its way gradually until the whole mass is in a state of incandescence to the very summit.

VIII. *The Kilns.*—A crowd of circumstances may affect the burning—the quality of the fuel, the direction of the wind, etc. Generally it takes 120 to 150 hours to calcine properly 70 to 80 tons of limestone.

It is almost impossible in long-flame kilns, 20 ft. to 25 ft. high, to burn the paper layers of limestone sufficiently without overburning the lower; in the case of rich lime this is not a matter of much importance, but in that of argillaceous limestone it is fatal, because if overburned it falls into powder and becomes good for nothing. The steam of the water contained in the limestone aids by its expansion in the burning of the upper layers: thus the limeburner prefers the stone just out of the quarry to that which has lost its water.

The burning of argillaceous limestone is also very difficult in kilns heated with coal, the latter being mixed with the stone. The draught is affected in many ways, by changes in the direction or in the force of the wind, by any damage done to the sides of the kiln, by the fact of the pieces of limestone being too unequal in size, and thus not being equally mixed with the coal, and many other accidents which cause the lime to be burnt too much or insufficiently.

IX. MM. Donopp and Deblinne set forth the differences which exist in lime calcined by means of wood, coal, and peat.

1. Lime burned with wood is generally whiter than that produced with other fuel.

2. Lime calcined with peat, slaked and mixed with an equal quantity of water, always precipitates more rapidly than that which has been burned with wood.

3. The calcination with coal produces lime which precipitates very promptly, when, after having been slaked, it is mixed with a certain quantity of water.

Consequently, it is in the interest of builders to employ lime burned with peat or coal, because as its residue does not contain the alkaline principles of lime burnt with wood by the mixture of the ashes, the mortars of which they form part will be of superior quality.

X. Rich lime is obtained from the purest limestone; it is called *chaux grasse*, because when slaked the paste is fine and greasy to the touch. This kind swells and throws out more heat than the others. Reduced to a paste and exposed to the air, it dries by the evaporation of the water which is not in combination with it, absorbs a portion of the carbonic acid contained in the air, and in time acquires considerable hardness; this hardness is much accelerated by the substitution of a current of carbonic acid gas for atmospheric air. In this state, and with the aid of small moulds, tiles and slabs may be made which take a polish when rubbed upon a fine stone, and resemble the finest white marble.

The following analyses of the composition of several materials producing rich lime are by M. Berthier, engineer:

Iceland Spar: — Pure carbonate of lime. The elements are:

Lime	0.564
Carbonic Acid	0.436
	1.000

Carrara White Statuary Marble.— The matter which is insoluble in acid is pure quartz. The elements are:

Lime	0.554
Magnesia	0.001
Clay and quartz	0.010
Carbonic acid	0.435
	1.000

Limestone of Saint Jacques, Jura.— Compact, yellowish in color, forms the basis of the Jura mountains. The elements are:

Lime	0.546
Magnesia	0.009
Clay and quartz	0.015
Carbonic acid	0.430
	1.000

Limestone of the Jurassic formation, forming the superstratum of the iron mine of La Voulte in the Ardéche— compact, yellowish, shelly, density, 2.67. The elements are:

Lime	0.541
Magnesia	0.006
Oxide of iron	0.005
Clay and quartz	0.022
Carbonic acid	0.426
	1.000

Coarse Limestone, tertiary formation in the environs of Paris, very shelly. The elements are:

Lime	0.556
Clay and quartz	0.015
Carbonic acid	0.429
	1.000

Fresh-water Limestone of the environs Nemours, Seine, and Marne—compact, yellow, rather cellular, and very sonorous. The elements are:

Lime	0.548
Magnesia	0.009
Clay and quartz	0.010
Carbonic acid	0.433
	1.000

Fresh-water Limestone of Œnigen, near Constance, Algeria—composed of remains of birds, saurians, and fish, contains a large proportion of organic matter. The elements are:

Lime	0.504
Magnesia	0.018
Clay and quartz	0.069
Carbonic acid	0.409
	1.000

The two following are due to M. Vicat:

Vichy Limestone.—This stone, from the amount of clay which it contains, forms the limit of rich limestones. The elements are:

Lime	48.80
Magnesia	4.76
Oxide of iron, clay, and quartz	2.80
Carbonic acid	43.64
	100.00

The composition of the lime produced from the above stone is as follows:

Lime	86.00
Magnesia	4.76
Oxide of iron, clay, and quartz	5.00
	100.00

The rich lime, which swells most, is evidently the most profitable; but its employment should be restricted to ordinary masonry in elevations; if used for underground or water work, the mortar in which it enters will not harden, but crumble away.

XI. *Chaux Maigre*, or poor lime, so called from the fact that when mixed with water, of which it absorbs but a small proportion, it is short and hard, not sticky and unctuous, like *chaux grasse*—it scarcely effervesces at all. It is produced from limestone containing mineral oxides and magnesian products in considerable proportions. Like the preceding, it is quite unfit for use under water or in damp places.

XII. *Hydraulic Lime.*—When *chaux maigre* possesses the special property of hardening under water, it is called hydraulic lime. M. Vicat subdivides the various kinds under three heads, according to their rapidity of hardening:

1st Class.—*Medium Hydraulic*, containing 82 per cent. of lime and 18 per cent. of clay.

2d Class.—*Hydraulic Lime*, containing 74 per cent. of lime and 26 per cent. of clay.

3d Class.—*Eminently Hydraulic*, composed of 70 per cent. of lime and 30 per cent. of clay.

The first sets after immersion for fifteen to twenty days; the second, in six to eight days; and the third in two to four days. The lime is considered to have set when it will support a knitting-needle, filed square at one end, and loaded with a weight of 10 ounces, without any sensible depression being produced. In this state it will resist the finger with a pressure of 10 to 12 pounds. A fragment of it will not bend, but break.

The hydraulic limes have little color. They have generally a muddy grey, unburnt brick, or yellow tint. Their swelling, as compared with the unctuous limes, is scarcely noticeable. The best and dearest of all the kinds known in France is that of Saint Quentin.

XIII. *Analyses of the Limes.*—The following table contains the results of analyses by MM. Berthier, Rivot, Delesse, and H. Deville, of the best known hydraulic limes, ten being of the class called "hydraulic," and six of the denominated "eminently hydraulic:"

Percentage of the Elements of these Limestones.

	"Hydraulic."	"Eminently Hydraulic."
Carbonate of lime....	51.33 to 89.2 per cent.	52.47 to 82.5 per cent.
" magnesia	In 1 case 40.91; gen. 2 to 3 per cent.	44.25 in 1 case; gen. 1.5 to 4.5 p. c.
Clay...............	5.50 to 15 per cent.	3.25 to 23 per cent.
Gelatinous silex.....	15.3 in 1 specimen only.	None.
Quartz sand and clay	15.0 " "	"
Alumina, with a little oxide of iron.	2.6 " "	"
Oxide of iron.......	Trace " "	"
Carbonate of iron....	0.58 in 1, and 6.2 in another.	3.0 per cent. in 1 case.
" manganese	None.	1.5 " "
Iron pyrites.........	0.80 in 1 specimen.	None.
Soda and potash.....	0.12 "	"
Water..............	1.0 to 4.5 per cent.	"

Percentage of the Elements in the Limes made from the above.

	"Hydraulic."	"Eminently Hydraulic."
Lime...............	53.82 to 78.29 per cent.	53.05 to 70 per cent.
Clay { Silica.........	10.25 to 26.14 "	13.40 to 29 "
Clay { Alumina......	1.54 to 8.69 "	Traces in 1 instance only.
Quartz sand.........	1.71 in 1 case; 35.93 in another.	" "
Magnesia............	From a trace to 1.34 per cent.	Trace to 39.71, in 3 cases only.
Oxide of iron........	Traces.	1 to 4.10 per cent. in 3 "
" manganese..	None.	4 per cent. in 1 "
Sulphate of lime.....	1.15 in 1 case; 1.24 in another.	None.

The best manner of preserving these hydraulic limes, when they come from the kilns, is to strew the bottom of the receptacle, which must be perfectly dry, with slaked and sifted lime, to the depth of about 3 in., and to place about the same quantity, or rather more, of the same over the top of the lime when the receptacle is filled.

When the proportion of clay exceeds 30 per cent. in hydraulic lime, it can only be slaked by means of boiling water. Powdered and mixed, this lime sets immediately. It does not, however, retain its hardness, but falls into powder or paste, according to the state of the atmosphere. This is called *chaux limite*, but it constitutes by comparison the limit between lime, the cements, and the puzzolanos.

NITRO-GLYCERINE EXPLOSIONS.

By CHAS. L. KALMBACH, M. E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

HAVING manufactured, solely for my own use, nitro-glycerine, fulminate, gun-cotton, and the dynamites, for nearly nine years, and having expended these materials under a great variety of circumstances, on land, in mines, and under water, I have been enabled to accumulate a great number of facts concerning their character. This experience has forced me to dissent from many important and universally received maxims, governing the storage, transportation, and use of nitro-glycerine, and the compounds made of the same. The fact that during all that time I have never met with the slightest so-called accident, confirms my faith in the deductions I have made from these observations.

Incidentally, while engaged in these labors, I discovered some improvements in the economical application, as well as in the compounding, of nitro-glycerine with absorbent materials, which improvements are covered by letters patent. Since, however, the specifications cannot relate my experience nor give the reasons for the system of rules I employ, I am induced to publish these notes to the end that the attention of others may be drawn to a system which has proved so eminently successful in my hands.

On the 14th of April, 1866, an explosion of nitro-glycerine occurred in Wells, Fargo & Co.'s office, San Francisco, resulting in great loss to life and property. A suit for damages arose, which is on record in vol. 15, p. 524, of Wallace's Reports, United States Supreme Court. From the testimony of the experts examined I quote: "Explosion of nitro-glycerine is produced by *percussion* and *concussion*, by a *high degree of pressure*, *but not by contact with fire.* If flame be applied it will burn slowly, without exploding, and when the flame is withdrawn it will cease to burn. It will also explode when *subjected to a heat of* 360 *degrees Fahrenheit.*"

I believe that the causes of explosion enumerated in the above quotation are to this day universally received as *axioms*, and that the fact of their unquestioned reception is the fruitful source of many accidents. I assert that but one of them is true and worth guarding against, namely: Nitro-glycerine will explode when heated to *about* 360 Fahrenheit. I will also state that all compounds containing nitro-glycerine will explode when heated to that degree. Simple concussion or percussion will not explode nitro-glycerine nor the dynamites.

A bottle or other frangible vessel partially filled with nitro-glycerine may be thrown with great violence, or from a height on rock and shattered without producing explosion. Surely here we have concussion or percussion. But what happens if a tin can or other strong flexible vessel filled with nitro-glycerine is subjected to such an ordeal? Such can will invariably explode when it strikes. The reason is evidently this: Arrested motion converted into heat. The glass bottle breaks by first contact, releasing the contents and allowing them to scatter, thus measurably continuing the motion; The flexible vessel, however, if strong enough, does not release them, but dents or flattens in the direction of the line of motion, thus reducing its cubical internal measure and producing on the contents rapid or rather *percussive compression.* This compression evolves an amount of heat exactly depending on the weight of the canister and the rapidity of its motion. For this reason it is difficult to explode the dynamites by similar force and under identical conditions. Being porous and capable of *yielding* to compression *to a degree*, they are incapable of evolving the necessary amount of heat for such explosion. It is possible, of course, to compact them sufficiently to neutralize that elasticity and evolve the heat necessary—in fact they are so compacted every time they are exploded in a mine, but it is evident that the conditions necessary are difficult to attain in the ordinary circumstances attending their storage, handling, and shipment.

Flame may be applied to nitro-glycerine, and it may thus be burned *on its surface* without explosion, provided: that the burning be interrupted before the unburned mass attains the explosive 360° of heat. The dynamites may be burned safely, because, being porous, they are poor conductors of heat and do not absorb it readily from the burning surface as the pure nitro-glycerine does. But it would be unsafe to burn a considerable amount of them in a thick metallic vessel, as the metal would carry the heat from the upper burning portion to the bottom and thus cause explosion.

The report next mentions "high pressure" as a factor of explosion. It is true that every explosion is attended, or rather *preceded*, by a high pressure, but it is a pressure developed instantaneously and the most *efficient generator* of the heat required. Pressure applied so slowly as to allow the dissipation of the heat generated *cannot produce explosion.* For this reason I doubt whether nitro-glycerine can be exploded in a vacuum.

The report then stated that: "It does not explode by the application of fire," which is true enough, if the fire be applied to the open surface of nitro-

glycerine of *normal temperature*, but that is certainly the only way in which fire may be applied to it without producing an explosion. A glowing coal, a hot iron, or a gas jet, applied to the bottom, or even the side, of a tin can, *will* explode it, for it will heat the film in immediate contact to the explosive point, producing an initial explosion. I say "initial," because if the vessel is entirely open and the point of contact small, the gases produced by the explosion of the film will merely throw the other fluid, nitro-glycerine, aside and escape with a crackling noise. If the can be full, or closed, or if the mass be frozen, or of great *height above the point of contact*, the whole will explode, because it cannot get out of the way of the pressure of the first or initial explosion, and this "initial" produces the required compression for the necessary instantaneous evolution of heat. On the other hand, a pan holding a moderate depth of nitro-glycerine may be set over a slow fire and entirely evaporated without an explosion, because the fire evaporation keeps the temperature below the explosive degree. Dynamite is subject to the same law, and differs only to the extent of its porosity.

Nitro-glycerine, if ever so carefully prepared and washed, will slowly decompose, yielding fumes of nitrous acid. If strictly confined these fumes accumulate and exert pressure, which pressure makes it peculiarly sensitive to percussion. This fact has been (doubtless) the sole cause of many, apparently mysterious, accidents.

I find, then, but a single primary cause for the explosion of nitro-glycerine, viz.: Heat of not less that 360 degrees Fahrenheit.

I also find that the most direct and efficient way to produce such a degree of heat is by percussive compression.

Knowing the primary cause of its explosion, it should be comparatively easy to make, store, transport, and use, nitro-glycerine in such a manner as to avoid all conditions favoring that cause.

It being important to give free access of, or rather to the, air, it should be stored in shallow, open, non-metallic vessels, which should not be filled to a greater depth than their diameter.

Stone, or earthenware, glazed inside, is the best material for such vessels, because: It is not affected by acids, not a good conductor of heat, and it is strong, stiff, and brittle. Such vessels are cheap and easily obtained everywhere, lasting an indefinite time. The flexible metallic can is supremely dangerous and unfit for the same reasons.

The shallow, open vessel gives another material advantage in the fact that the contents are always fully visible, and any change in appearance indicating dangerous decomposition may be at once observed and provided for, for it always *does* change in appearance long before a dangerous stage is reached.

When during, or rather immediately after, manufacture, the acids containing the nitro-glycerine are washed in an abundance of well agitated water of a *low temperature*, the precipitated, heavy oil has a white, curdy appearance not unlike buttermilk. It is then in its *very safest condition*, as it is impossible to explode it by any ordinary degree of compression. It is, however, just as strong as it ever is under other and more sensitive conditions. I have sent a rifle ball through a tin canister of it without producing explosion, and have fired a strong fulminate primer in another with the same result, viz., tearing the vessel and spilling the contents. When the latter experiment, however, was repeated with a strong champagne bottle the explosion occurred, because the sides of the bottle were strong enough to enable the primer to exert the requisite compression. Such nitro-glycerine, in a temperature of 70° F., will retain this appearance and this quality for one and even two months.

Since it adds so much to the safety it is worth the trouble to store a supply sufficient only for that length of time.

Such nitro-glycerine is peculiarly fitted for shipment and is safest to carry in boxed stone jugs, which are not to be filled quite full, say 3 gallons in a 5-gallon jug. Only a very gradual raising of the temperature will explode such jugs— no amount of crushing force being able to cause explosion, provided the nitro-glycerine remain fluid. As soon as it freezes it separates from the water and will remain so after thawing. Thus it can be made highly sensitive by repeated freezing and thawing. Frozen nitro-

glycerine is dangerous to handle and transport, because it is rigidly confined in its crystals which occupy a less space than the fluid they are formed of. The fracture of a dry crystal will often cause explosion. There is, however, one advantage in keeping nitro-glycerine frozen in store and it is this: When frozen the acidulous decomposition noticed on page 27 cannot possibly take place, but the nitro-glycerine remains perfectly unaltered as long as it remains hard. Since such decomposition is so slow as to be almost imperceptible, and since it is so easily checked and provided for by simple washing and a superposed film of water, I have always avoided freezing because of the risk involved.

I have, in the above, tried to give a full and intelligible exposition of the true cause of the explosion of nitro-glycerine and the means I have successfully applied to avoid unintentional explosion. I only hope that I have avoided all obscurity of expression, as that is the only chance for misapprehension.

CLEVELAND AND THE WORLD'S IRON TRADE.*

From the "London Mining Journal."

Duration of Supply.—The Cleveland ironstone has been estimated by Bewick to extend over an area of not less than 420 miles. Allowing a yield of 20,000 tons per acre, it has been calculated that the main seam of the district contains close on 5,000,000,000 tons. Not a few estimates have been made regarding the probable duration of this supply. Mr. Cockburn, manager of the Upleatham Mines, in a paper read before this Institute in the year 1869–70, calculated that first-class stone would be found in the Cleveland hills for 73 years to come, allowing an average weekly consumption of 75,000 tons. It is pretty well known that this consumption has already been surpassed. Including the ironstone vended from the Rosedale Mines of Messrs. Morrison and Leeman, and the Hinderwell Mines of Palmer's Shipbuilding Company, the total average weekly output of ore is now over 100,000 tons, so that, according to Mr. Cockburn's estimate, the period of the exhaustion of our best mineral—assuming a continued ratio of increase—is likely to be arrived at within (say) the next 60 years. Mr. Cockburn's calculation, I believe, leaves the top seam, as well as the upper and lower oolitic, intact, and yet Bewick placed the duration of the same source of supply at 680 years, and allowed 800 or 900 years as the limit of duration over which the inferior seams would be capable of extending. Mr. Jones, secretary of the Cleveland Ironmasters' Association, is reported to have stated in 1872 to the committee on the Cleveland Extension Railway Bill, that the supply of ironstone in the Cleveland district would last for a hundred years at an increasing ratio of consumption, and it was calculated by the same gentleman at that time there were about 300,000,000 tons under lease and worked, being equal to 37 years' consumption at the rate of 7,740,000 tons per annum. It is of little use taking into account the thin and inferior seams, as they are nearly all too coarse and silicious, and contain too small a percentage of iron to defray the cost of working. It is, therefore, on the main seam that the prospects and prosperity of Cleveland must depend. It would probably be found that with a more exact definition of the area of the ironstone field embraced within their calculations the fignres given by Messrs. Bewick and Cockburn would more nearly coincide than they now appear to do; but whichever estimate we accept, the period of the exhaustion of our supplies of ironstone is placed at so remote a date that it need not further enter into our calculations. It has hitherto been, and still is, the custom to speak of the ironstone of Cleveland as practically inexhaustible, and this we may here confidently assume to be the fact.

* From a paper read by Mr. J. S. Jeans before the Society of Cleveland Engineers.

Compared with other Iron Fields, the ironstone can be worked at a cheap cost. Until within the last three years its price did not generally exceed 3s. 6d. per ton, and it could be mined for 10d. per ton. There is scarcely any other district in which more economical results are obtained. In Lincolnshire, it is true, the ore is quarried at a cost of 6d. to 8d. per ton, and is sold at the mine for 2s. 6d. to 3s., but then the ironmakers of Cleveland will not hesitate to affirm that the Lincolnshire ore is not so uniformly well adapted for smelting purposes as the ore of Cleveland; and when it was found necessary last year to make use of it in lieu of the native stone, it involved no end of trouble in the working. Scotland has what seems at first sight a superior advantage to Cleveland in the closer juxtaposition of its minerals, the splint coal being found not unfrequently in the same measures that yield the iron ore; but both the splint or smelting coal and the blackband ironstone of Scotland are near exhaustion, and retrogression has consequently marked the course of the Scotch iron trade during the last two years. Staffordshire and Wales have such inadequate supplies of local ore that they are compelled to import the great bulk of what they consume from foreign sources. Northampton has of late been brought into considerable prominence as a source of supply, but the position of the district is even worse than that of either of the three older districts here enumerated, seeing that it labors under the insuperable want of a proximate source of coal supply. It is scarcely necessary to extend our comparison into North Lancashire and Cumberland, for in addition to the great cost and uncertainty attached to the mining of iron ore in these districts, the former with an ample supply of hematite is compelled to bring the great bulk of its fuel from South Durham, at a freightage rate of 8s. to 9s. per ton, while the latter, with a proximate supply of inferior coal, is chiefly dependent on the Cleator Moor district—a restricted and rather precarious source of supply—for its ironstone. Unaided and alone, the ironstone of Cleveland would never have placed that district in the proud industrial position it now occupies. The contiguity of the South Durham coal field, with boundless supply of the finest fuel yet found to be available for iron smelting purposes, has been the ladder on which Cleveland has mounted to exceptional prosperity. The Durham coal field is within 1s. 6d. or 2s. per ton of Middlesborough, and the development of the Durham coal trade has followed that of the iron trade of Cleveland in an unvarying ratio of increase.

Iron Manufacture on the Continent.—Spain has large tracts of iron ore in the district around Bilboa, now being largely developed by English capital, but there is no sufficiently contiguous coal field to favor the erection of ironworks on the spot. Besides the coal of Spain is very inferior in quality, containing a low proportion of carbon, ranging from 45.5 to 82.0 per cent. Russia also has to combat the difficulties of a limited and inferior coal supply, the total area of its coal field being not more than 100 square miles, while the coal often contains as much as 17.1 per cent. of ash to 38.7 per cent. of carbon. A good deal has recently been done to develop the mineral resources of Russia, for we find in a recently published return it is stated that there were 1174 iron mines in operation, and that the production of pig-iron was at the rate of 354,000 tons per annum; but, notwithstanding that there are numerous rich deposits of iron ore, the scarcity and inferiority of the supplies of fuel must always operate to the detriment of its metallurgical industry. Commencing in Luxemberg and terminating in France, there is a field of ironstone 150 miles in extent, which corresponds in geological position with our own. The ore varies from 6½ to 16½ feet in thickness, and yields about 32 per cent. of iron. The same field may be followed into Alsace-Lorraine, where it attains a uniform thickness of 13 feet, and where the mines are close to the furnaces. Mr. I. L. Bell has found that iron can be made here more cheaply than on the banks of the Tees, but the fuel available for smelting purposes in this part of the Continent is so deficient alike in quantity and quality that, in spite of cheaper labor and other collateral advantages, there is not much scope for any great development of production unless, indeed, there shall meanwhile be found greater

capabilities of fuel supply than are now known to exist. There is no other European country that threatens to come within sight of England in the manufacture of iron, if we except Belgium, which has long been held up as the *bête noir* of the British industrial, and of whose rivalry we are still hearing reports from day to day. No one who knows anything about the relative industrial conditions of the two countries will seriously admit that any ultimate danger is threatened to England from Belgian competition. Here and there a Belgian firm has wrested an order from the English iron trade; and the opposition thus confronting us has been more seriously felt since the tide of industrial prosperity commenced to ebb, some 15 or 18 months ago. But there can be no permanency in the hold which the Belgians have been able to seize upon the markets of Europe. So far as its natural resources are concerned, Belgium is one of the most impoverished nations in Europe. Its coal field does not cover an area of more than 510 square miles, as compared with 5,400 square miles of coal area in Great Britain. Its collieries are generally worked under very great difficulties, and its ironstone is all but exhausted. Out of 700,000 tons of iron ore required to produce the 610,000 tons of pig-iron made in Belgium in 1871, not more than 100,000 tons were raised in Belgium itself, the residue being almost entirely from the Grand Duchy of Luxembourg, so that the bulk of the ore has to be carried a distance of over 100 miles, while much of the ore does not contain more than 26 to 27 per cent. of iron. But, in addition to these drawbacks, neither the ironstone nor the fuel supplies of Belgium are equal in quality to those of England. The fact is that the Belgians hold their high position among industrial nations not because but in spite of the natural resources of their country. Cheap labor, an avoidance of all avoidable waste, contentment with small profits, and patient industry have really and solely made Belgium what it is; and I hope that I shall not be considered presumptuous if I venture to add my opinion that it has reached its utmost limit of development so far as the iron trade is concerned. Already it imports from England a great deal of the pig-iron and fuel required for its manufactures, and so long as it is handicapped to this extent it is manifest that "if England to herself do prove but true," nothing that Belgium can do need furnish cause for alarm or apprehension.

American Competition.—And now I approach what is to me the most interesting, and to others will appear the most important, part of my subject—the consideration of the rivalry that the iron trade of England is henceforth to experience from America, and probable extent to which American ironmakers will in the future supplement or supersede the iron production of this country. Hitherto, it must be admitted, the iron trade of America has not made the progress that was reasonably to be expected, nothwithstanding that it has been unnaturally stimulated by a protective tariff of import duties. There are five ironmaking regions in the United States, of various extent and importance. Chief among these is the region of Lake Superior, the great tract of country lying west of the Alleghanies. It extends by Lakes Superior, Huron, and Erie towards New York State, and by Lake Michigan into Wisconsin, Illinois, and Indiana, and abounds in ores yielding from 50 to 60 and even 70 per cent. of iron. In the Michigan iron range there is an immense deposit of the best black magnetic ore, which yields from 65 to 69 per cent. of iron. For the most part these deposits lie within easy reach, and mining is never deep and difficult as in this country. Often it is mere quarrying, and the "bluffs" which contain the ores frequently allow of tunneling, with a slope under the ground. All through the States, indeed, there is an abundance of iron ore of a quality rarely found in this country, and in the Lake Superior region alone 1,197,000 tons of iron ore were raised in 1873, valued at the mines at over $8,000,000. The fuel of America is generally well adapted for smelting purposes, and distinguished for a high degree of purity. It is not, however, so much in the superior quality of its resources as in their magnitude that America will probably overtake and ultimately surpass Great Britain. The coal fields of the United States are estimated by Prof. Rogers to cover an area of 196,650 square miles, while a further coal area of

7,530 square miles is contained in the British Provinces of North America, making together a total coal area of 200,000 square miles, as against 5,400 square miles of coal area in Great Britain. These figures simply represent the difference between an easily exhaustible and a practically inexhaustible supply, for although much of the coal of the United States may not be within reach of working, there will be millions upon millions of tons left unworked when the last ounce of available coal has been extracted from the coal fields of Great Britain; and if ever England is reduced to the necessity of importing her fuel from America or China, "the day of her manufacturing prosperity — to say nothing of her supremacy—will have gone for ever." At the present moment the production of pig-iron in America is a little over a third of the total production of Great Britain.

The total number of blast furnaces available for use in the United States, according to the most recent statistics, is 575, and of that number 348 only were in blast. It is rather remarkable that, notwithstanding the abundant coal resources of the country, more than 200 of these furnaces burn nothing but charcoal; of the remainder 181 burn coke, and 187 burn anthracite. One of the greatest difficulties in the way of the development of the American iron trade is the general absence of a proximate coal field to the ironstone measures. In some cases the coal has to be brought a distance of many hundred miles to be smelted on the spot where the ironstone is found; and in other cases the iron stone is brought a long distance to the coal. The drawback incidental to the geographical association of coal and iron ore is, to a large extent, discounted by the splendid facilities of transport that exist throughout nearly the whole of the United States. Minerals can be carried at a cheap rate along the Ohio, the Delaware, Lake Michigan, the Mississippi, and other inland seas, to the advantages of which, in this country, we are complete strangers. It is undoubtedly true that labor is at the present time cheaper in this country than in America, but labor is an item of cost that can be adapted to circumstances, whereas natural resources are not. There is a want of definite information respecting the fuel supplies of America; and in the last report of Her Majesty's Secretaries of Embassy and Legation a doubt is expressed as to whether the coal resources of America are equal to keeping pace with her requirements in iron smelting. But every accession to our knowledge on this matter only tends to strengthen the conviction that the fuel of America is not only practically illimitable, but in the main admirably adapted for smelting purposes. Americans have also of late years essayed to excel the manufacturers of Cleveland in their greatest achievements. The "Cambria" furnace at Johnstown, with a capacity of 15,020 cubic feet, and the "Lucy" furnace at Pittsburg, yielding 475 tons of Bessemer pig-iron per week, have become quite historical; but these furnaces have recently been left in the shade by one built on the banks of the Alleghany, which sometimes produces as much as 101 tons of pig-iron in a day, and can yield with unvarying regularity from 650 to 660 tons of foundry iron in a week. We have never heard of a blast furnace in Cleveland that yielded anything like this result, despite the fact that we have long boasted of having the biggest and most productive furnaces in the world. Habitual optimists on the one hand, and rest-and-be-thankful economists on the other, have been diligently trying to explode the notion that America will one day become a competitor with England, not only in United States markets, but in all other markets in the world. They say that America has not the capital necessary to enable her to overtake and rival England, forgetting that the accumulation of capital is only a work of time. They say also that the purchasing power of money is so much less in the United States than in Europe, that the manufacturers of the former could never successfully compete in the markets of the latter; but it is easy to perceive that closer assimilation in this essential is not only attainable, but certain, sooner or later, to be attained through the exigencies of commercial intercourse. It was, moreover, believed not long ago that, owing to some defect in the clay of which American blast-furnaces were built, the cost of providing plant and keeping it in repair would seriously handicap Amer-

ican manufacturers; but we now learn that the "Mount Savage" brick of the States excels the Scotch or German, or even the famous Stourbridge, so that unless the rich ores of America prove too much for any clay, the building of monster blasts will probably become the rule of the future. Taken as a whole, therefore, it may fearlessly be maintained that America lacks none of the essential elements of manufacturing greatness, while her ultimate resources surpass those known in Europe by as much as a mountain surpasses a mole-hill.

General Conclusions.—Cleveland is now the only known iron-producing district in Europe likely in the future to come into active competition with America, and that if the resources of America were less than they are, the development of the Cleveland iron trade would probably proceed at a much more rapid pace. Hitherto the American iron trade has been defensive rather than aggressive in its tendencies. It has been content with seeking to supply home requirements. But this endeavor it has realized with a success at once startling and inimical to the manufacturers of Europe. Within the last three years the United States have fully doubled their resources for the production of pig-iron, and they have increased their production of malleable iron from 1,500,000 in 1871 to 2,000,000 tons in 1873. It is not necessary to weary you with figures showing you how the exports of all kinds of iron from this country to America have fallen off within recent years, or how that falling off has affected Cleveland in particular. It is abundantly evident that America has learned to depend upon herself, and year by year we will continue to lose our hold upon American markets until we are shut out altogether. But while America will become her own ironmaster, she is not likely for many years to seek for custom outside her own territories. She may produce iron more cheaply than it can be imported from England with a high protective tariff in her favor; but she will not be able to undersell the British manufacturer in the markets of Europe. This, then, is the field in which the Cleveland ironmasters must labor in the future; and we think we have already shown that his resources are such as to enable him to cultivate this field more successfully than any visible competitor. In this field the sun of his prosperity will only set when the fuel available for smelting the ironstone of this district becomes exhausted. That, however, must be regarded as a very remote event, notwithstanding the calculations of Mr. Jevons and other statisticians; and if there is any truth in the commonly accepted estimate that there is just about sufficient fuel left in the Durham coal-field to smelt the ironstone contained in the main bed of Cleveland, our capitalists may rest in undisturbed security, for no one will wake up in their generation to find that exhaustion has at length overtaken us.

THE SEWAGE OF PARIS.

From "The Engineer."

In certain respects Paris is in a worse position for the satisfactory disposal of her sewage than London. It is true that her population is much smaller, and the area of collecting ground more manageable; but, on the other hand, the great distance of Paris from the sea renders it impossible to use the latter as a recipient of the sewage sent down from the former. Thus the cost of constructing anything like the terminal canals of our own metropolitan main drainage system would be so enormous that the idea could not be entertained for a moment. In one word, Paris sewage cannot be sent to sea in special channels. For years it was poured into the Seine almost without protest, but the extension of the city, and the consequent augmentation in the volume of sewage to be disposed of, at last became so great that the condition of the river could no longer be tolerated. The construction of a fine system of main sewers, tolerable perfect in every respect except that they lacked a satisfactory outfall, supplied,

no doubt, an additional stimulus to exertion. It became possible at least to collect the sewage of Paris, a thing which was impossible while thousands of subsidiary sewers debouched into the river. Then came a period during which experiments were carried out with various processes for the purification of sewage, all with more or less unsatisfactory results. A farm was established, however, on which a considerable quantity of sewage was distributed with fair promise of success, and at last a commission was appointed on the 27th of August, 1874, to investigate and report on the condition of the Seine, and suggest means for insuring its purification. The commission have just published their report, which we have much satisfaction in stating confirms the views which we have all along expressed. They find that the only satisfactory mode of disposing of the sewage of Paris is to run it on to land; in other words, the system to be adopted is a combination of irrigation and Mr. Bailey Denton's method of downward filtration. The extent of land is to be much larger than Mr. Denton would probably deem necessary; but it is certainly smaller than we think would suffice if the soil were not of great depth, and so porous that the sewage would be fairly purified even if no crops were grown. Having premised this much, we shall now proceed to consider the report more in detail.

The commissioners commence by describing the existing state of the river. The Seine is joined before entering Paris by the Marne, the Yonne, and several smaller streams, all exposed to certain chances of pollution. Yet the condition of the water is stated to be, on the whole, good. Fish flourish in the stream, which runs over a bed of white sand visible through the clear water. Pollution commences as soon as the stream fairly enters the city, but it is limited in character and of small importance until the bridge at Asniéres has been reached. The great main sewer running north through Paris discharges itself close by at Clichy, and the contents of this conduit appear to be incredibly nasty. The report goes a good deal into detail about dead dogs and cats, and scum, and organic refuse. The picture drawn leaves, indeed, little if anything to the imagination, and nothing to be desired. In moderate weather the Stygian flood keeps the middle of the stream, but in heavy rains the force of the current in the river is too much for that issuing from the sewer, and the sewage is compelled to run close to the left bank. On this bank a filthy deposit is left as the river falls. Of this we shall say nothing in the way of description. It will suffice to state that nothing that we have ever read or heard of can, apparently, be more insufferably disgusting. The pollution extends a long way down the stream—how far we do not know with precision. Oxidation and deposition do their work by degrees, and the nuisance is abated after miles have been traversed. But the Seine, we need hardly say, is never really pure—we use the word in the mildest sense—after it has passed through the bridge at Asniéres. Such being the position of affairs, the commission had to consider how best to improve matters. Five distinct schemes for effecting this object appear to have been carefully weighed. The first was the extension of the main sewers to the sea—which was at once set aside because of the expense. The second contemplated the extension of the sewers to the confluence of the Oise. But this would only carry the nuisance to the banks of the Oise and was accordingly rejected. The third scheme was essentially novel. The sewage was to be diluted by the addition of pure water near the outfalls, and still suffered, as before, to escape into the Seine. We need hardly say that this ingenious proposition was rejected. Fourthly, it was proposed that the sewage should be passed through large filtering beds, and the clear water delivered into the Seine. This scheme was rejected because, as the commissioners point out, filters require incessant attention, and, after all, they only remove solid impurities. The fifth scheme was to construct immense settling tanks near the outfalls, to collect the dead dogs and other solid matters. This would obviously only eliminate a portion of the evil, while the settling tanks, which would need to be very large, would prove a dangerous nuisance in hot weather, and this idea was accordingly abandoned. Nothing remained but irrigation, downward filtra-

tion on Denton's system, or purification by some of the numerous patented schemes before the world. That which appeared most likely to succeed was the precipitation system. To test its value, a series of experiments were carried out at the suggestion of M. Chatcher, Inspector-General of Mines. Reservoirs were established at Clichy on a great scale, and on the 11th of October the commissioners saw as much as 600,000 tons of sewage treated by the sulphate of alumina process. The result was, that the water was discharged clear, but not pure. Careful experiments made in 1868, showing that two-thirds of the nitrogen and one-third of the volatile or combustible materials of the sewage were left in the water, which was unfit for any, even the commonest domestic uses, and could not possibly be discharged into a river without contaminating it. What was true in 1868 is, of course, equally true of the process in 1875. The report deals very fairly with this question, and shows honestly and dispassionately why it is that all these sewage processes must fail, except as palliative measures. It is estimated that Paris discharges annually about 260,000 cubic yards of solid matter suspended in the sewage. Now, a depositing process would have to provide for the disposal of this huge mass of mud. How can this possibly be effected? If by artificial heat, the cost would be enormous. If by natural means, the space occupied by the filthy mass would be very great—not much less than 150 acres. A nuisance would be unavoidable; and the process of desiccation could scarcely be carried on at all in winter. But when the mud had been so far dried that it could be carted or otherwise manipulated, what would become of it? The theory of the believers in "processes" is, that it would constitute a very valuable manure, worth as much as 50s. a ton, or more. The report before us explodes this fallacy. In France, at all events, dry sewage mud is only worth from 6f. to 10f. a ton, which is just about the cost of the chemicals used. The expense of pumping, drying the mud, and otherwise manipulating the sewage, remains undefrayed, even if a ready sale could be had for the mud. So that the cost of carrying out the process would be very heavy, even if the value of the residuum were maintained, which is, we may add, to the least degree unlikely, as it would not pay to transport so worthless a material to any distance by road or rail, and the landowners in the vicinity of the purification works would soon find that they could dictate their own terms, because the authorities would be compelled to sell the product at any price, and rest content so long as they get rid of it. The commissioners estimate that the adoption of the sulphate of alumina process would cost the ratepayers of Paris and its environs £40,000 a year, and very wisely rejected it without further scruple, as being at once unsatisfactory as regarded the effluent, unmanageable on a large scale, and expensive.

After a review of the various schemes we have cited, the commissioners go on to state that the solution of the question must be sought not in chemical processes of purification, but in the combined action of the soils and plants on sewage. They are very careful, however, to qualify this statement by adding that the soil must be permeable. They thus evidently clearly appreciate the conditions under which sewage can best be applied to irrigation purposes. Experiments were carried out by the commission to test the advantages of downward filtration; and Mr. Denton will rejoice to learn that the results obtained were eminently satisfactory. A glass vessel half a metre high, filled with earth and sand from the plain of Gennevilliers, clarified for a long period sewage discharged on the surface. The commission analyzed the sewage with which they had to deal, and the variety of plants which they proposed to cultivate, and they have arrived at the conclusion that for each crop 7,800 cubic yards of sewage, or, say, 1,306,000 gallons, should be applied per acre. On this point the commissioners are probably wrong in principle, as the quantity appears to be excessive, but they are apparently right, taking into consideration the nature of the soil with which they have to deal, in assuming that each acre of irrigated land will purify about 24,000 cubic yards of sewage per annum. We shall not attempt to reproduce here a description of the existing works at Gennevilliers, where the irrigation system has for two years been at work; it

must suffice to say that about fourteen miles of ditches distribute sewage, raised at Clichy by centrifugal pumps, over a farm of about 353 acres. The commissioners carefully examined the farm, and investigated all the particulars connected with it, and they finally arrive at the conclusion that the only remedy for the pollution of the Seine is the direct application of the sewer water to agricultural purposes, and that a permeable soil, like that at Gennevilliers, is favorable to the cultivation of market garden produce, plants for manufacturing purposes, and grass, and that no injury to the health of those living near the sewage farm is to be feared. We cannot, for lack of space, enter into a detailed consideration at this moment of the arrangements proposed by the commissioners for carrying out their scheme. The works existing at Gennevilliers were constructed with a grant of £40,000, made for the purpose in 1872. In 1874 a similar sum was voted for extension of the works, and, when these are constructed, about 2,470 acres will be available for irrigation, and these will dispose of about fifty millions of tons of sewage per annum, or half the total volume of water now collected by the sewers of Paris. As regards the other half, it appears that west of the present farm more land can be obtained at Gennevilliers, to the extent of nearly 3,000 acres, and it is estimated that all this might be brought into use by an outlay of £200,000. This would dispose of the whole of the sewage of Paris. Land might also be obtained near St. Germain, and the commissioners think that it would be well that this should be examined before taking another tract at Gennevilliers.

We have done little more, it will be seen, than give the heads of one of the most interesting documents yet contributed to the literature of sewage; we shall return to the subect. Meanwhile, we would express the hope that the publication of this report may do something to place matters on a more satisfactory footing in this country. If it is once proved that there is no way of disposing satisfactorily of sewage but by turning it on land, we may hope that the Legislature will interfere to such an extent as will simplify the present process of obtaining sewage farms. The energies of corporations are too often wasted now on various schemes more or less conflicting, and it is too commonly argued that it is much better to try a process than incur the cost of purchasing a sewage farm. While an alternative remains for adoption, time and money are certain to be wasted by local boards. The report of the Paris Commission has done much to prove that irrigation without alternative must, in the long run, be adopted, and we trust the conclusion will be accepted as nearly, if not absolutely, final.

NOTES OF A VISIT TO MINES AND IRONWORKS IN THE UNITED STATES.*

By I. LOWTHIAN BELL, F. R. S.

From "Iron."

Mr. Bell began by saying that in the year 1871, one-half of the iron produced in England was exported to foreign countries, and one-fourth of this half was despatched to the United States, in all about 750,000 tons. In the year 1874, however, the States only took 130,000 tons, and it was stated that during the three years the producing power of that country had risen from two and a half millions to four millions of tons. It is a matter of great interest to the British ironmasters to learn whether this extraordinary growth is due to the stimulus of our own excited markets, and whether the increase can be actively employed when iron falls in value to what experience has accustomed the world to pay for this commodity. In touching upon the question of transport, which so nearly relates to the manufacture of iron, he said that the raw material in America has to be carried over distances quite unknown in this country. This applies

* Read before the Iron and Steel Institute.

also to the manufactured product. A great deal is done by water, and, as an instance, he gave the cost of conveyance of coal from Pittsburg down the Ohio. Twenty thousand tons of this mineral are sometimes embarked on board a flotilla of flat-bottomed boats, and conducted by one steamer, for a distance of 1,600 miles at something under 1s. per ton, which includes the cost of bringing back the empty barges. The entire question of internal intercommunication of the United States has experienced great changes in consequence of the enormous development of the railway system. The Hudson River, which is accessible by the Great Eastern Railway for seventy-five miles above New York, has a double line of rails running alongside its stream beyond the city of Albany. Thus the locomotive has not only, in many cases, displaced the marine engine, but it has brought mineral districts into communication with each other, which, without it, would in a great measure have remained useless. A limited quantity of charcoal iron can be, and is, produced from the rich ores of Lake Superior, the Iron Mountain of Missouri, and Lebanon in Pennsylvania; but the quantity would have remained insignificant had the rail not enabled these minerals to be conveyed to the coal of the Shenango and Mahoning Valleys, and to those of the Lehigh, Delaware, Ohio, and others. The railway system has grown into dimensions far exceeding those in England, the land of its birth. At the end of 1873 the United States had 76,651 miles of road, against only 16,082 miles in England. The average cost per mile in the latter has been £36,582, and in America not one-third of that sum. In the latter case, however, the Americans have had the advantage of getting their land for a mere trifle, but they have had to contend with scarce and dear capital, and with materials and labor far more costly than in England. They have not constructed such substantial lines, however—the convenience of the many being allowed to override the possible injury to the interest of the few. The working charges in the States absorb 65.1 per cent. of the gross earnings, and in this country only 53 per cent. The rates of carriage also vary, some charging 1½d. per ton per mile, and others only ½d. Looking at the fuel consumed in the manufacture of iron in America Mr. Bell first referred to charcoal, and remarked upon the large quantity of forest land to be found. In the earlier history of the iron trade it was almost exclusively used in the blast-furnace, and even in 1854 one-third of the pig-iron produced in the United States was smelted in the charcoal furnace, or about 300,000 tons; now it is 500,000 tons, or one-fifth of the entire make. It is mostly used for railway carriage wheels. The prices of charcoal vary according to the district, and Mr. Bell gave instances. He spoke of the system of weights and measures employed in the American ironworks, and said that this is one of the few things which the people there had done badly. Not content with introducing our unmeaning ton of 20 cwt. of 112 lbs., they have two distinct tons, one of 2,000 lb., and the other of 2,440 lb. Mr. Bell calculates that 46,000 acres of timber fall annually to provide fuel for the charcoal furnace. Less than 200 acres of a four-feet seam of coal, in the county of Durham, would produce the same weight of coke as is obtained from 46,000 acres of American forest. Coal is more abundant in the United States than in any other part of the world, and all kinds are found. In some places natural gas is used for puddling, reheating, &c. Of pit-coal itself there are 192,000 square miles, as compared with 8,000 square miles in the United Kingdom; and Mr. Bell thinks it may be doubted whether there is any similar area in the world in which a larger proportion of the surface is occupied by coal-bearing strata. The anthracite fuel is much used in the blast-furnace, indeed, out of two and a half millions of tons of pig-iron smelted last year, about one-half was the product of furnaces burning anthracite. From the position which these beds of anthracite coal occupy, it would appear as if, after their original formation, an enormous amount of lateral compression had been experienced by the districts in which they lie. This force has raised the strata into a succession of waves, as it were, the slopes of which vary from an angle of 20 to 45 degs., and occasionally descending to a depth of 200 to 250 fathoms or more. In some cases, this compressive power

has been so great as to have forced one ridge back over its neighbor, to such an extent as to convert what is the floor of the seam of one place into the roof at another, and, from a similar cause, the quantity of coal which has accumulated at the anticlinal axes of some of these coal undulations is so great as to afford a face of 40 to 60 feet, or even more, in thickness. In some cases denudation has carried off not only the sandstones and shales, but a portion of the coal itself, the bared edge of the seam is found immediately under the alluvial matter of the surface. The coal is sometimes quarried; indeed, at Mauch Chunk, there is an open quarry of coals 10 acres in extent, the face of the seam having a height of 70 feet. Peculiar appliances are necessary for extracting this coal, and Mr. Bell described them briefly. The largest blocks known as "lump" coal are chiefly consumed in the blast-furnaces, the others go for various purposes. The "stove" coal is that used for domestic fires, and commands the highest price. Anthracite coal is regarded as a natural coke, as it often contains as much as 93 per cent. of solid carbon. The height of the seams and the nature of the "thrust" by working out the support of a roof lying at a high angle, is the cause of great loss in "pillars," 25 per cent. of the whole contents of the seam being the average. The American coal master has also to contend with a considerable quantity of small, which is entirely valueless, and many acres of land, near the older pits, are covered with it. Sometimes as much as one-half of the whole produce of the mine is thus rejected, but the average is about 20 per cent. of the coal actually drawn. The men engaged in the anthracite mines work from eight to ten hours per day, and are paid on a sliding scale, according to the selling price of coal. Describing bituminous coal, Mr. Bell stated that this is worked without producing much small, and is largely used in a raw state in the blast-furnaces in the Mahoning and Shenango Valleys. In the eastern coal-fields, near Pittsburg, a celebrated coking coal is raised. Near Connellsville the seam is 10 or 11 feet thick, and the coal lies so soft in the ground that a man without the use of powder can shovel a ton an hour into the trams. The entire produce of the mines is converted into coke, and this is considered the best of any in the United States. Mr. Bell, however, thinks that it is greatly inferior to Durham coke. The cheapest coal he heard of is obtained for supplying one of the large ironworks, and, exclusive of royalty, it is delivered at the furnaces for about 3s. per ton. After describing the coal in the various fields, he went on to consider another item of iron manufacture, viz., the supply of flux for blast-furnaces. He stated that there is a vast extent of carboniferous or mountain limestone in America, frequently very near the pig-iron works. Near Baltimore the shells of oysters, which are found in great abundance at Chesapeake Bay, are used. They contain 95 per cent. of carbonate of lime, and are a very inexpensive substitute for lime itself. The United States contains abundant quantities of iron ore of all kinds except the spathose ore, which is very scarce even in Europe. The ironstone of the liassic and oolitic seams, which furnish about one-third of the pig-iron made in the United Kingdom, seems to be entirely wanting in the States. The speaker described first the magnetic iron ore of Lake Champlain, its peculiarities, mode of deposition, &c. Relative to the specular ore of Lake Superior, which is valuable from the cheapness of its extraction, its abundance, and its freedom from deleterious ingredients, he remarked that the contents of the mines are chiefly obtained by open quarry work. The ore yields something like 67 per cent. in the blast-furnace, and is pure enough for the manufacture of Bessemer iron. Mr. Bell next noticed the Iron Mountain deposit. It is of easy reduction; indeed, a furnace only 40 feet high, with boshes of 9½ feet, blown with cold air, will make 100 or 120 tons per week of grey iron, with less than 24 cwt. of charcoal; with moderately hot air 150 tons per week can be run with 20 cwt. of fuel. The yield of the ore may be taken at 65 per cent. The author then described in detail, various deposits of limonite, or brown hæmatite, which he saw, and afterwards touched upon those of red hæmatite; clay and blackband ores also came in for a share of attention. Mr. Bell, in treating of the blast-furnaces, referred first to the establishments which

have been founded for promoting scientific training and education, and he spoke very highly of the earnestness and devotion which characterizes those engaged in the mining and metallurgical industries of the States. He criticised the various matters in which he thinks an improvement might be made, and recommended those worthy of adoption in this country. He stated that the Lehigh makers are a little behind the age in the question of fuel. In furnaces 55 feet high, with boshes of from 17 feet to 18 feet, the anthracite used in smelting an ore yielding 50 per cent. with 12 cwt. of ironstone was about 35 cwt. Perhaps this was due to a want of sufficient temperature of the blast, and so the insufficient height of the furnace. Where ironmasters had been bold enough to erect furnaces of 72 feet high, their experience has proved eminently successful, for the fuel consumed has been reduced to 25 cwt. per ton of iron. In the matter of wages, skilled men are paid at rates below their brethren in England. The furnace-keepers in 1874 received 8s. 6d., against 10s. and 12s. paid last year in the North of England. As a rule, in the States, they have more men employed to do the same work, and this, added to some superiority in arrangements, enables English makers to smelt a ton of iron for considerably less than the amount paid in wages in Pennsylvania. Mr. Bell spoke highly of their blowing machinery. He stated that the make of the 55 feet and 60 feet furnaces of grey iron may be taken at 200 tons, and that of the larger at 300 tons per week. Remarking on the very large make of some of the Pittsburg blast-furnaces, Mr. Bell stated that their whole secret lies in forcing the air into the furnace at a high pressure, 8 lb. to 9 lb., and in immense volume. The ready reducibility of the ores is also favorable to a large make. Going on to the malleable ironworks, Mr Bell remarked that the quantity of pig-iron puddled is less than in this country, as a large quantity of old rails are annually worked up in the mills. The greatest number of puddling furnaces in any one establishment is at the Cambria Works, at Johnstown, Pennsylvania, but they cannot turn out above 600 tons of puddled iron per week, although their make is equal in steel and iron rails to 100,000 tons a year. In the States there are 899 double and 2,063 single puddling furnaces, which together only produce about 2,000,000 tons of puddled iron, or 1,750,000 tons of finished iron. The prices for puddling vary considerably in different localities. In Troy, the rate is as low as 19s. per ton, in the Lehigh Valley 21s. 9d. is paid, and at St. Louis and Chattanooga 24s. 6d. At Pittsburg 22s. 7½d. was paid at the time of Mr. Bell's visit. He could not give a very satisfactory account of the progress of mechanical puddling in America. He referred at length to the Danks' progress, and stated that during his visit to Messrs. Graff, Bennet & Co.'s, where they are in operation, the work was going on in a satisfactory way, but the furnaces were not used at nights. Mr. Bell believes that rotatory puddling will ultimately be achieved, and it may be the result of some modification of the apparatus invented by Mr. Danks. Whenever hand puddling is superseded by mechanical means, Mr. Danks will deserve great credit for the assistance he has already rendered, not only in perfecting the furnace itself, but in devising other appliances required in manipulating large masses of iron. Mr. Bell noticed the three-high rolls in finishing mills, which are in the United States very generally adopted. The next subject for remark is that of the manufacture of steel. The make last year of Bessemer steel reached 175,000 tons, of which 135,000 tons were used for Bessemer rails. At the Bethlehem Iron Works Mr. Bell saw hot ingots of steel weighing a ton each, taken direct to Siemens' furnace, out of which they were charged and drawn by means of hydraulic cranes. When at a suitable temperature, the ingots were brought to the cogging-mill, which was provided on each side with feeding tables, the invention of Mr. Fritz. These tables consist of two strong frames, the breadth of the rolls, and long enough to support the ingot when rolled out. The frame is furnished with a series of rollers, and supported on the standards themselves is also a roller, the latter forming thus a continuation of the platform of rollers placed on the frames. A man at a small double-cylinder engine is able to set the whole of the rollers on the two feeding-tables, as well as those carried on

the standards, in motion, which he changes at will, by simply reversing his engine. As soon as the ingot is partially on the table the rollers are started, and the ingot is propelled towards, and drawn through the rolls, when it is received on the table behind the rolls. The moment this is done, a second man, by means of hydraulic machinery, raises the two tables to the level of the grooves formed by the middle and top roll. While this is being done, powerful screws reduce the aperture in the rolls, and the ingot, by reversing the rollers, is passed to the front, when the feeding-tables are lowered again to their original position. Underneath the front feeding-table is a traversing frame, to which movement, by hydraulic pressure, can be communicated parallel to the rolls, and at right angles with the rollers of the table. Attached to this traversing frame is a row of five strong bars coming through between the rollers, and bent at the top ends at right angles. By the use of hydraulic power, these bars can be raised and lowered, so that, by means of the traversing frame, they are made to travel at will between the rollers, and pass up through them. The moment the ingot is lowered on the front feeding-table, the bent ends of the bars catch it on the left-hand edge—looking towards the rolls—and turn it over, the traversing frame moves to the right, and the five bars, now projecting above the feeding-table, push the ingot opposite the second groove. The rollers are set in motion, and the ingot is passed through the rolls as before, and this is repeated for each groove in the rolls. In this way the ingots are reduced to the size fit for the finishing mill, without a man ever touching them. After being cut in suitable lengths, they are charged while hot into a second Siemens' furnace, and heated for the rail mill also, with three high rolls, and a masterpiece of rolling machinery for strength and accuracy. Mr. Bell thinks that all that can be said of the blast-furnace process, and the malleable ironworks of America, is that they are keeping fairly up with the British, but, in the Bessemer works, we must look to the United States for superiority of arrangement and some improvement in machinery over our own. He considers the Americans, like ourselves, have done nothing in imitating the French by running the iron from the blast-furnace direct into the converter. Little or no steel was being made in America by the Siemens-Martin steel process. An establishment had been erected on the banks of the Monongahela River, near Pittsburg, for carrying on the Blair process of making steel. In principle there is no novelty in Mr. Blair's method, which cousists of deoxydizing ore and melting the iron sponge so obtained in an open hearth with pig-iron. The first step in the process has been tried over and over again by Chenot and others ; and Dr. Siemens has paid an immense amount of attention to the second. The consumption of charcoal and fuel was considerable, and did not seem to be a good substitute for the combined action of the blast and puddling furnaces. Mr. Bell thus describes the Blair process :

"Mr. Blair conducts the operation in an upright retort, but circular in section, 4½ feet, in diameter, and 40 or 50 feet high. In the upper eight or ten feet, however, is inserted a metal pipe about 3½ feet in diameter, so that for this distance from the top the working space is an annulus 4½ inches across. Heat produced by burning carbonic oxide, obtained from a Siemens' producer, is applied to the outside of the retort, and heat is similarly communicated to the inside of the 3¾-feet pipe. Ore and charcoal are charged into the top of the annular space, which is thus exposed to heat from the outside and inside, instead of, as with Chenot, having the heat only applied to the exterior. The sponge is retained by Mr. Blair, as with Chenot, in the lower portion of the pipe, which is kept closed until it cools. One such retort as that described gives about 2 tons of sponge in the twenty-four hours. The difficulty which besets this and all other modifications of dealing with iron in so fine a state of division as it exists in iron sponge is its proneness to oxydation. Hitherto it seems to me the direct process, as it is termed, has met with the most success at Landore. The pig-iron, after being melted, has blocks of ore thrown in ; the carbon and silicon of the bath reduce the oxyde, and the metallic iron is instantly taken up by the bath of liquid metal. Very different must be the action on sponge, which, when thrown

into the furnace, will float on the melted pig, and, being exposed to carbonic acid at a very high temperature, will, to some extent, infallibly be reconverted into oxyde. So far as I was able to learn, two parts of pig-iron and one of sponge lost about 20 per cent. in the furnace. Now, if it be true, as I have heard stated, that a mixture of wrought and pig-iron can be fused in an open hearth with a loss of 6 per cent., it follows that a considerable portion of the sponge used in Mr. Blair's process must be reconverted or reoxydized. The specimens of steel I had an opportunity of examining indicate entire success, so far as a mere question of quality in the product is concerned. There seems to be no doubt that, in obtaining the sponge-iron, Mr. Blair has made a notable step in advance of M. Chenot, and I am far from wishing it to be understood that I indicate an unfavorable opinion on the future commercial merits of the scheme."

Mr. Bell then considered the labor question, noticing the varying amounts of the wages, paid in different districts. While in one locality an iron-ore miner is paid 12s. 9d. per day, in another he is satisfied with 4s. 8d. In other districts, particularly in the South, the iron mines are worked by convict labor. The wages must necessarily be higher in the States than they are here, as the cost of living is so much greater. Mr. Bell referred at length to the question of import and export duties. He states that he is fully aware how unpopular, among a great number of the iron manufacturers, the present tariff would be—indeed, they rather seek to add to the restrictions it already imposes. In the United States itself, the opinions are very largely divided as to the benefit of protection, as applied to native industry. The protectionists frequently argue that we ourselves retained protection to native industry, until we felt that we were independent of foreign competition; and now that we no longer fear this, and require the necessaries of life for our people we are found crying out for free trade. They appear to overlook the fact that the chief opponents to free trade in England thirty years ago had as much reason to fear foreign competition as any branch of industry in the States need dread the importation of British iron. Mr. Bell gave instances of what has been the effects of production in the manufacture of iron. Soon after 1871, the price of iron commenced to rise in England. At that period, something like one-third of the metal consumed in the United States was imported from England. The change in value here at once made itself felt in America, and foundry iron was commonly sold at £10. This remarkable change led to an immediate increase in the number of blast-furnaces, many new ones being added by the end of 1873. Mr. Bell concluded his paper by dwelling at length on the benefits of free trade, and combated certain arguments enunciated to the contrary by the Secretary of the American Ironmasters' Association.

Mr. Bell expressed his satisfaction at the recompense which the meeting had given him, and stated that he had brought specimens of some of the ores he had met with in the United States, and they were in the room for inspection.

THE UTILIZATION OF WASTE STEAM.

From "The Engineer."

The number of non-condensing stationary engines in use is very large, and the discharge of their steam into the atmosphere instead of into a condenser represents a great expenditure—we shall not say waste—of fuel. Such engines are, however, seldom adopted without reasons sufficiently powerful to insure the rejection of condensing apparatus. Locomotives and portable engines for obvious reasons cannot be constructed on the condensing principle, and it will be found that stationary non-condensing engines are only used where fuel is exceedingly cheap, where water is too scarce to be used for condensing purposes, or in iron-works, where all the steam needed and more, can be raised by the heat, which would otherwise be wasted, escaping from puddling and ball furnaces. No

one thinks of utilizing waste steam under such conditions, and we shall not further refer to the subject in connection with them. Indeed, it is very difficult to see to what purpose the steam could be applied in such cases, with one somewhat limited exception—the warming of feed water—but the conditions of its employment to the best advantage in this way are well understood, and we need not dwell on them. In large cotton mills and weaving sheds considerable quantities of steam are required not only to heat the mill, but to supply the damp atmosphere requisite to the successful weaving of fine sized fabrics. In paper mills and calico printing establishments much steam is used in heating rolls, and the use of steam for warming water in brewing, etc., is very common. The question which presents itself, and which we propose to deal with here, is this: Is it better to use the steam which has left an engine for heating purposes, or to condense that steam and provide a separate boiler, or additional boiler power in some other way, to supply the steam needed for heating purposes? We happen to know that there is a curious conflict of opinion on this point, which renders it well worth discussion in these pages. We must regard the question from two distinct points of view. In the first place we have to deal with those conditions under which much more steam passes through an engine than can be used for heating purposes. This is the condition ordinarily obtaining in cotton mills. In the second place, we have presented for consideration those cases in which as much, or more, steam is required for heating purposes as for driving machinery. It will be found on examination that these varying conditions materially modify the problem to be solved.

As regards engines driving cotton mills, it will be seen that the whole question turns on the value obtained from the use of a condenser. Thus, if we suppose that 10 per cent. of all the fuel burned to make steam is expended in heating the mill, and that it could be shown that the gain from the use of a condenser represented but 10 per cent. of the whole consumption of coal by the engine, then it would be better to use a non-condensing than a condensing engine; and it will also be clear on examination, that as the volume of steam required for heating purposes augments in proportion to the power due to the condenser, so will the economy of condensing as compared with non-condensing diminish, until at last a point will be reached when it is a matter of indifference which system we adopt, while a further demand for heating steam would render it better to abandon condensation altogether. We are aware that this is opposed to the views of some engineers, who maintain that it is better in all cases to keep heating and power distinct. But our views are nevertheless demonstrably sound, provided the conditions are such that the working of the engine will be no more affected by the use of the steam in heating pipes than it would be if the steam were discharged directly into the atmosphere, a condition which we admit is not always obtainable. As regards cotton mills, however, it will be found that, as a rule, the quantity of steam required for heating purposes is much smaller than that given off by the engine—probably amounting to about one-sixth only. In a word, the engine rejects more heat than can be utilized, and this being the case, it is better to use a condenser than not. This proposition at first sight appears anomalous. Because an engine gives out more heat than we require, why should we refrain from utilizing that heat? The contradiction is easily explained away, as will be seen in a moment.

In order to ascertain the power derived from the use of a condenser, it is a very simple matter to take an indicator card and measure the relative areas of the condensing and non-condensing portions; or, which comes to the same thing, to measure the average pressure in each portion. Thus, for example, if we take the case of a condensing engine using steam of an absolute pressure of 75 lb. on the square inch expanded five times, we shall have an average theoretical pressure of 39 lb. From this must be deducted back pressure, say, 5 lb., allowance being made for imperfect vacuum and port resistance. The effective pressure will be 34 lb. on the square inch. If, however, the condenser were suppressed, the average driving pressure would remain unaltered, but the back

pressure would be increased from 5 lb. to about 17 lb., and the effective pressure would be reduced from 39 lb. to 22 lb. For the moment we shall regard the consumption of steam as remaining unaltered; therefore, the loss of power due to the loss of pressure represents the gain due to the condenser, which in the case cited would be about 36 per cent.; that is to say, for every 100-horse power given out by the engine with the condenser, it would without it, give out but a fraction over 64-horse power. It is extremely improbable that any circumstances could arise in connection with a cotton spinning or weaving mill in which so large a quantity of steam as that representing 36 per cent. of the whole power employed would be required for heating purposes, and, therefore, to abandon the condenser would be false economy. It may, however, be as well to state here that the engine when working without a condenser would not use as much steam to produce 65 horse power as it did when with the aid of the condenser it gave out 100-horse power, simply because the internal condensation either in the cylinder or jacket would be sensibly diminished when the frigorific influence of the condenser was withdrawn. The temperature of steam of 75 lb. pressure is 307.4 deg.; that of steam of 5 lb. pressure is 162.5 deg. The range of cylinder temperature would, therefore, with condensation, be 144.9 deg. The temperature of steam of 17 lb. pressure is 219.45 deg., and without condensation the cylinder temperature would consequently range through 87.95 deg. only. Precisely how much this circumstance would affect the quantity of steam condensed in the cylinder it is impossible to say without direct experiment, but that it would reduce the loss is beyond doubt. On the other hand, however, if the same conditions of expansion and pressure were maintained in both cases, the engine must have a larger cylinder in order to develop the required power, and a new element of waste would be introduced by the extension of the metallic surface with which the steam would come in contact. These matters are, however, rather beside the question we are discussing, and we may take it as proved that the engines used in our manufactories owe over one-third of their power to the assistance rendered by a condenser—in many cases much more—and that the most economical use to which heat rejected by their cylinders can be applied is embodied in the production of a vacuum.

It has been proposed that the exhaust steam might be utilized in heating mills while the condenser was retained. In other words, the exhaust pipe might be led up and down and round about a mill, and then return to the condenser. The steam would then be partially condensed in the pipes and partly by the jet. Such a scheme is eminently delusive. In the first place, the maximum temperature in the pipes would not exceed that due to the pressure in them, or, say about 170 deg.; in the second, back pressure would be occasioned by the resistance of the pipes and their bends; and lastly, it would be practically impossible to maintain all the joints in such a heating pipe air-tight. In one word, we should have a bad heating apparatus and a wretched vacuum combined. It would be waste of time to discuss this aspect of the question further.

There remain for consideration cases in which it is essential that large volumes of high-pressure steam shall be used in manufacturing operations, such as boiling pulp for paper making. Whether the supply is or is not to be had from the exhaust pipe of an engine depends altogether on circumstances. The total quantity of heat utilized by a steam engine represents so small a proportion of the whole heat contained in steam, that it is certain steam intended for heating purposes will lose little if it is first used to drive an engine. Cases may arise in which steam of a total pressure of, say, 70 lb. on the square inch is required for some manufacturing purpose. Now the consumption of fuel in producing 100 lb. steam is practically the same as though the pressure were 70 lb., and it will be very good economy to generate steam of the higher pressure named and pass it through a steam engine, which will then play the part of a reducing valve, and give out all the power due to a pressure of 30 lb. on the square inch. The engine will, it is true, work against a back pressure of 70 lb., but no one looks for economy here. As the steam

must be had in any case, it is as well to get all we can out of it, and in this way in many works from five to 50-horse power might be had, in one sense, for nothing. Under such conditions as these, the cases we have named, in which engines are worked with a heavy back pressure, become perfectly legitimate examples of the utilization of waste steam. So long as the pressure of the steam required for boiling or heating is moderate, but still considerably above that of the atmosphere, it is good policy to use strong boilers, and carry the pressure high enough to work an engine; but this rule will only apply, as we have already pointed out, in another case, when the whole volume of steam required for heating is much greater than that which would be rejected by the engines. In few words, when the primary use of steam is to heat, then the condenser may be suppressed; when the primary use of steam is to give out power, then the condenser cannot with advantage be dispensed with.

A somewhat complex case is presented when the final pressure in the cylinder of a condensing engine is greater than that of the atmosphere. Under such circumstances it is obvious that more steam remains in the cylinder at the end of the stroke than is required to produce a vacuum. The surplus may be utilized for heating purposes in many cases with advantage. On some of the American river boats it is employed very ingeniously to urge the fires. The moment the exhaust valve opens, the steam, of perhaps 30 lb. pressure, escapes in part through a suitable secondary valve, and rushing up the chimney creates a draught. The secondary valve instantly closes, however, and in doing so opens a free communication with the condenser, to which about one-half the whole volume of steam goes, the remainder urging the fires as we have said. By a somewhat similar arrangement the steam could obviously be used for heating purposes. It must not be forgotten, however, that it is very bad economy under most circumstances to discharge steam of 30 lb. pressure either into the air or a condenser.

THE PROTECTION OF BUILDINGS FROM LIGHTNING.

By R. J. MANN, M.D.

From the "Journal of the Society of Arts."

When a lightning discharge falls from a charged cloud to the earth, it of necessity takes the line of least resistance that is open to it, whatever that may be, and if that line lies along sufficiently large and absolutely continuous metallic substance, the effective resistance to its passage is so small that no mechanical violence, or heating effect of any consequence ensues. This, therefore, at once indicates what the first expedient in providing artificial protection from mechanical injury must be. A continuous rod of good conducting metal must be carried from the top of the building to the ground. Then when the stroke of lightning chances to fall upon the building, it goes by the easy way, and flows harmlessly and silently through the metallic rod to the earth, and the less perfect conducting materials of the house, such as bricks, mortar, cement, and wood, are not touched. In order, however, that this desirable result may be brought about, it is essential that the metallic rod shall be large enough to carry quietly and harmlessly the largest discharge that may have, under any circumstance, to pass through it. As a rain-water pipe must be made large enough to carry safely away the largest rainfall that can occur, if flooding is to be avoided, so the lightning conductor must be made large enough to carry the heaviest lightning that can strike. And it is even more important that this should be secured in the case of lightning than in the case of rain, because an overflow of fire is a more serious matter than an overflow of water. Some elec-

tricians consider that an insufficient lighting conductor is better than none at all, because there have been instances again and again where buildings have been saved from mischief on the discharge of lightning, although the lightning conductor that has effected their protection has been burnt up and destroyed. As in such cases, however, a new lightning-rod has to be immediately supplied, it would have been obviously better that the conductor of double capacity should have been erected in the first instance. The author of this paper must also add that he has some reason to look upon the conclusion itself with doubt. There is always danger from fire if a lightning conductor of insufficient dimensions happens to be carried along near combustible materials. The lightning stroke is certainly more likely to fall where a lightning conductor, of whatever kind, is placed than it would be if there were no such appliance. The lightning conductor, in such circumstances, may be "the slight acquisition of power which destroys the tottering equilibrium; the last straw which breaks the camel's back;" alluded to by Mr. Preece. There certainly is as much danger in the interpolation of a lightning-rod in such tottering equilibrium as there would be in "a horseman galloping along over the ground." What the damage is that a conductor of insufficient size may effect is well illustrated in the practice of firing charges of gunpowder in mines by the platinum fuse. A fine wire of platinum is made part of a current of electrical communication in the midst of a charge of gunpowder. When a current of electricity is passed through the wire it becomes red hot, on account of not having sufficient size to convey the electricity without derangement of its molecules, and the red hot wire fires the gunpowder. If the platinum wire had had the thickness of a pencil, instead of a hair, the same charge of electricity would have passed without the explosion of the gunpowder. Another very telling illustration is supplied by the not uncommon occurrence, where a small soft metal gas-pipe is attacked by a powerful discharge of lightning, and the gas-pipe is fused, and the gas set light to. What the dimensions in a lightning conductor are that would fulfil this essential condition of giving sufficient capacity for the safe transmission of the largest possible discharge is yet an unsettled question. In his excellent monograph already alluded to, Mr. Preece argues that a No. 4 telegraph wire of galvanized iron, which is a quarter of an inch in diameter, is sufficient for the protection of most dwelling-houses, because No. 8 wires, of only half this capacity, are found practically to protect telegraph posts from damage by lightning. It is, however, most probable that in the case of telegraph wires a lightning discharge is distributed among several of these protectors, as several are brought into the system by the conducting telegraph wires above. Mr. Preece alludes to two No. 8 wires having been fused and destroyed by lightning in one season. M. Arago gives the case of a chain 128 feet long, formed of successive rods of iron, one quarter of an inch in diameter, which was fused through its whole length by a lightning discharge. On the other hand, rods of iron, three-quarters of an inch in diameter, have been known to convey very powerful lightning strokes to the ground harmlessly and safely. In the instructions of the "Académie des Sciences," drawn up by Gay-Lussac and Pouillet, 1823 and 1824, a square iron bar, three-quarters of an inch in diameter, was adopted as ensuring ample capacity for all practical purposes. An iron pipe, having the same sectional mass of metal, is better than a solid rod, because the electrical force is transmitted by the surface of the conductor, and a pipe obviously has more surface than a solid rod of the same relative mass. Galvanized iron is better than uncoated iron, in the first place because its surface is protected against rusting; and in the second place because the zinc conducts with three times greater facility than iron. A rope of galvanized iron consisting of 42 strands of sixteenth of an inch wire is a very convenient form of conductor, on account of its ready flexibility, for purposes of conveyance and adaptation to angles and irregularities of a building, and on account of the long stretch that can be made in continuous lengths. If a conductor is made of several pieces, it is indispensable that those pieces

should be joined together by absolutely perfect metallic union, or there will be greatly increased resistance to the passage of the electric force in consequence of the gaps. In strands of galvanized iron the galvanic surface affords a very easy path for the electricity, and the iron core is a stubborn metal in reference to heat, and not readily destroyed. A 42-strand wire rope of the character that has been described affords as much surface, and is in all respects as good a conductor as a strip of stout galvanized iron four inches broad. Copper is a five times better conductor than naked iron. A rope of copper wire, one-sixteenth of an inch thick, and with 28 strands, would be as efficient as a galvanized iron wire rope of 42 strands. Dimensions of this value are recommended, because they are unquestionably equal to any demand that can be made upon them, and because there is yet some measure of uncertainty in regard to the possible intensity of the electrical discharge in exceptional cases. It may, perhaps, be necessary to point out, in regard to this particular bearing of the subject, that the sole reason why telegraph engineers incline towards conductors of smaller capacity is that reduction in cost virtually increases the number of lightning conductors that are used. This is a very important practical consideration. But, in the face of it, and after patient and long-continued weighing of the whole subject, the author of this communication, in his experience as a lightning engineer in South Africa, notoriously a favorite haunt of the thunder storm, adopted the 42 strand rope of sixteenth of an inch galvanized iron wire, and never found any reason yet to regret his practice on this point. The provision is ample for buildings of considerable elevation. The mistake of employing too small a conductor is a very common one. Within the last few weeks the author of this paper himself, in company with his excellent friend, the secretary of the Society of Arts, came upon a lightning conductor attached to a very handsome recently restored church in the vicinity of London, in which a single very small galvanized iron wire was used, where a lofty spire was part of the structure, and where, apparently, the thin wire passed down the face of this spire along a casing of wood shingles. The author submits that if this is not one of the "last straws that might break the camel's back in the circumstance of a tottering equilibrium," it ought to be. The advantage of copper, in contrast with iron, for employment as a lightning conductor, is simply that it heats less easily under an electric discharge, is very stubborn to melt, and that it is the best of all conducting substances. Its disadvantages are, that it is much more costly than the galvanized iron conductor which furnishes an equal facility of passage, and that, as a metal, it undergoes a molecular change, from the frequent passage of strong currents of electrical force, which materially affects its conducting power. It must also be remarked that copper is a very much better conductor than brass. Copper costs about one-third more than brass, but it transmits electrical currents eight times as well. Messrs. Sanderson and Proctor, of Huddersfield, and of 18 Queen Victoria Street, have recently contrived a copper tape, or strap, for lightning conductors, which costs about one shilling the foot, and which is so flexible that it possesses in a very considerable degree the advantageous properties of rope. It can be bent round the inequalities of a building with the utmost facility, can be manufactured in continuous lengths to any extent, and can even be coiled for convenience of transport. This copper tape is three-quarters of an inch wide, and an eighth of an inch thick, and therefore contains a sectional area of a little more than a tenth of a square inch of solid metal. This will most probably be found to be ample for all ordinary purposes, and it can, of course, be readily doubled in any case where lofty buildings have to be protected.

The French electricians, who are unquestionably very high authorities in matters of this class, commonly employ metallic ropes, in preference to bars, for the main stretch of the conductor, because they possess a larger sectional area than solid rods of the same diameter, are more easily placed, and adapt themselves to irregularities of structure without the trouble of forging, because they can be readily made of any continuous lengths that can be required, and, in the case of iron, can be easily galvanized, and be-

cause they are so supple and more manageable. They consider that an iron cable should have a diameter rather more than twice and a half that of copper cable (27.3 millimetres against 1 centimetre) to have the same efficiency. M. Callaud, an eminent French electrical engineer, who has very recently printed an excellent book on the "Paratonnerre," records that a rope of copper, four-tenths of an inch (one centimetre) in diameter, employed as a lightning conductor at the church of Sainte Croix, at Nantes, and which was made of seven strands, having each seven threads of wire of a gauge of 0.039 of an inch (one millimetre) in diameter, had certainly transmitted several very heavy electrical discharges without suffering any injury in its own substance, and that a similar rope of one-fifth smaller diameter (eight millimetres) previously employed had been injured by lightning discharges. Copper bars a fifth of an inch (exactly five millimetres) have been known to be as much injured by a single storm as by ten years of exposure and rust. M. Viollet Leduc, on the other hand, states that copper ropes seven-tenths of an inch (eighteen millimetres) in thickness were burned at Carcassone. From a consideration of these facts and some others of a similar character, the French electricians of the present day employ ropes of copper from four-tenths to eight-tenths of an inch (one to two centimetres) for each 82 feet of height. Mons. R. Francisque Michel, who has printed an interesting notice of the faulty state of the lightning defence of the public monuments of Paris, with some allusion to the views of M. Callaud, in *Les Mondes* of October, 1874, considers that a rope of galvanized iron wire should have a diameter of eight-tenths of an inch, to afford efficient protection under ordinary circumstances. M. Callaud prefers that metallic ropes should be constructed upon hempen cores, on account of the greater pliability which this contrivance gives. It has been already observed that lightning conductors require to be of larger size in proportion to their length. The law which rules this proportion is simply that the facility of electrical transmission in any conductor is in the exact ratio of the co-efficient of the conductibility of the metal of which it is composed, multiplied by the number representing the section of the rod, and then divided by the number representing its length. The durability of any rod is, in general terms, in proportion to the square of its diameter. M. Melsens, a high French authority, prefers that there should be several conductors of small size rather than one large one; and it is at any rate generally agreed that a large building should be furnished with several conductors, and that when several conductors are combined into one stem, that stem must be of a size sufficient for the safe transmission of all the electrical force that can be furnished to it by the contributory branches.

If it so happens that metallic cables have to be joined, the individual wires of the connected ends must be untwisted, and spliced or mingled together, and then be bound tightly round with wire in such a way that the whole can be dipped into melted solder, or solder be carefully run in over a fire. Cables may be satisfactorily connected with rods by turning a spliced loop upon their ends in this way, and by then binding this loop in upon the rod by means of strong screw nuts. Monsieur Michel, in speaking of the need of renewing the efficiency of the public lightning conductors of Paris, makes the excellent practical suggestion, that the ends of rods requiring to be spliced in continuous electrical communication should have plates of soft lead firmly nipped in by screw power between the ends that are to make contact, the entire joint being afterwards enclosed in a sufficient investment of solder.

The disintegrating energy of an electrical discharge is mainly expended upon the extremities of a conductor. It effects the most marked molecular disturbance on the part where it first falls, where most probably the first meeting of the two antagonistic forces occurs, and where the terms of the new alliance have to be arranged, and also on the part by which it has to issue from the conductor to the ground—the great natural reservoir of the reserve of the energy. On this account lightning conductors require to be expanded and amplified both at their summits and at their roots or base. The French Academie

des Sciences directed that the top of the conductor should be a bar of iron two and a quarter inches in diameter, whether square or round, tapering up to a blunt conical copper point, shaped to an angle of thirty degrees. The pointed termination of the conductor is a matter of some practical consequence, because it establishes a slow and gentle discharge of an accumulation of electrical force at high tension, as is illustrated in the ordinary experiment where the charged conductor of an electrical machine is quietly discharged by the presentation of a sharp needle to it. De la Rive held that a metallic ball was quite as efficient for an upper terminal as a point. But when a great number of lightning-conductors are brought near together, as in protecting the buildings of an extended town, there is no doubt that if they are pointed at the top they serve to saturate an approaching cloud, and to deprive it of its sting before it comes within striking distance. After the city of Pietermaritzburg, in Natal, had been largely supplied with pointed lightning-conductors, under the author's fostering influence, the actual discharge of violent lightning strokes within the area of the town became almost unknown. During several years the only cases that came under the author's notice were the tops of two chimney-stacks somewhat damaged, and a few lofty blue gum trees shattered.

On account of the facility with which it could be supplied by ordinary workmen, the author adopted a terminal for the upper end of the conductor in the colony of Natal, which proved very effective and satisfactory. In this arrangement the top of a galvanized iron rope was inclosed in a tube of stout sheet zinc, finished at the summit, for the sake of ornament, by a gilded ball of turned wood, above which the strands of the wire were opened into the form of a sort of brush. Each conductor, in this way, had 42 points of its own, and the augmentation of terminal capacity was secured by the addition of the external zinc tube. The tube also supplied a ready and convenient means of attaching the conductor to chimney stacks, or to other protruding parts of the building.

The especial function and power of points is very pleasingly and completely illustrated by a series of three experiments devised by M. Gavarret, Professor of Natural Philosophy to the Faculty of Medicine at Paris. He first charges the prime conductor of an electrical machine to the highest point of tension that it can contain ; he then places near to it an earth-connected rod, furnished with a point directed towards the conductor, and he shows that the tension which can be produced in the conductor diminishes constantly as the angle of the neighboring point is made less. He next provides a Leyden jar that discharges itself by spark through a given neighboring point, and unscrewing this point, and replacing it by a crown of points, he shows that thenceforth the same jar will only discharge itself silently, and without a spark. He then so arranges the jar that it discharges by sparks below the plane of a neighboring terminal point, and on fixing lateral points below that plane the spark-discharges immediately cease.

Perhaps, however, the most telling proof of the beneficial influence of points in relieving the tension of an excited electric is that which is given by a very simple and pretty experiment, most easily performed. If a living man stands upon a stool with glass legs, and is placed in electrical communication with the prime conductor of an electrifying machine at work, with a gold-leaf electrometer on the table three or four yards away from him, and holds in his hand a sewing needle, with one finger pressed over the point, the gold-leaves of the electrometer show no manifestation of the electricity in the operator, until he unmasks the needle by withdrawing the finger from its point, when the gold-leaves immediately start asunder, under the influence of the stream of electricity which is poured out upon them through the point, even at that distance. Or yet, again, if a large tassel of strips of light tissue paper is made to throw its several strips out into a divergent brush, by electrifying the tassel from a machine, the tassels of the paper collapse together immediately upon unmasking upon them a needle point held in the operator's hand at the distance of two or three feet away. There is one very important result of the employment of terminal points to lightning rods which should never be lost

sight of. A lightning rod with efficient points, and in satisfactory operation, might be grasped by the hand of a living man, even when in action, with entire impunity, because, on account of the continued drain set up by the points, the rod can never assume any dangerously high tension. A conductor acting without a point, on the other hand, is in a state of very considerable tension when it effects its first discharge, and if it were grasped in the same way by a hand, would, in all probability, strike through that hand some very inconvenient and possibly painful proportion of the discharge. Conductors that have been acting silently with points have been seen to be struck by sinuous tracks of fire, indicating dangerous discharges of high tension, when they have been disarmed of their points.

Platinum has very generally been recommended for the construction of the terminal points of lightning rods, because it is one of the hardest known metals to melt, and because it is also not easily oxydized. The points are shaped to an angle of from 7 to 10 degrees at the top, and are made a trifle less than two inches (5 centimetres by the French) long. In this form they are screwed firmly into the top of a rod of copper, which is then in its turn connected with a cable or metallic bar below. The terminal rod is usually made of augmenting size as it descends, and is generally projected from 12 to 20 or 30 feet above the building that is to be protected. Platinum points are specially made for lightning conductors in Paris. They are supplied by Collins, of 118, Rue Montmartre; Beignet, of 96, Rue Montmartre; and Detouche, of 222, Rue St. Martin. The cost of a platinum point at these houses, grafted on brass, and from 50 to 70 centimetres (1.9 to 2.7 inches) long, is from 16 to 22 francs. For better finished work, with larger needles of platinum, grafted upon copper, the cost is from 60 to 200 francs.

M. Francisque Michel considers that the points may be quite as advantageously made of silver alloyed with copper, in the same way that it is when used for coining silver money, that is, containing 165 parts of copper to 835 parts of silver. Such points have the unquestionable recommendation that this alloy possesses a very much higher conducting power than platinum, which has 12 times less conducting power than silver and 11 times less than copper. Messrs. Sanderson & Proctor construct their points very neatly, by simply twisting the copper tape spirally at the end, after the fashion of an auger, and then filing away the termination of the flat metal into the shape of a sharp angle. The entire terminal is also glided over the copper to the extent of eight inches. This kind of point has the very obvious recommendation that it forms a continuous portion of the actual rod, and needs no joining or attachment.

The French electricians strongly recommend, upon the ground of the experiments of Professor Gavarret, that the lightning-rod should be terminated by a cluster or a crown of points, instead of by one alone, and M. Callaud has given two sketches, in his treatise, of forms of terminal points that have been adopted in France, in one of which a circle of ten points radiates at an angle of 45 degrees round the base of the principal terminal, which rises some inches above them; whilst in the other a kind of plume of points feathers out from the base. M. Beignet, of the Rue Montmartre, exhibits a model of the multiple point which the French electricians most affect. Mr. Francis, of Southampton Street, Strand, constructs a very simple and efficient multiple point of copper. The Hotel de Ville at Brussels, which is a very large building, and which has been furnished with lightning rods upon a very complete scale, by M. Melsens, a distinguished Belgian electrician, is literally bristling with points. It has 228 points of copper, and 36 points of iron, in its system.

The lower termination of a lightning conductor requires the exercise of even more care than its upper end, because it is less constantly and less generally under observation, and any shortcoming or mistake in reference to it is fatal to the efficiency of the rest of the arrangements, however judiciously they may have been carried out. A faulty termination of the earth connection is, of all else, the most common and frequent blunder, in relation to lightning conductors, that is made. As that is one of the terminations of the artificially provided conduct-

ing track, it must be of enlarged dimensions, as has been already explained. It must be in very intimate communication, not merely with the ground, but with the freely conducting portion of it. If a moist contact can be secured by insertion of the rope or rod into constantly damp soil, the contact need only be large enough to diffuse what is known as the electrolytic action—that is the chemical disintegration of corrosive metals at moist contact when electric currents are operative—over a fairly extended space. If the contact is made with dry earth, the surfaces must be very large indeed. The drier the material that is involved—unless it be an extended system of continuous metallic substance, such as the underground iron tubes of water and gas supplies in towns, which are among the most efficient ground terminals that can be adopted—the more expanded must be the surfaces of communication and contact.

It is worth while here to make a passing allusion to a few flagrant instances of faulty construction in the establishment of earth contacts of lightning conductors on account of the strength of the illustration that dwells in such failures. In a well known case of a lighthouse at Genoa, which was injured by lightning, and which was presumed to have been furnished with seemingly efficient protection, it was found that the bottom of the conductor had been plunged into the interior of a stone rain-water cistern, primarily constructed especially to keep out the infiltration of the sea, and therefore well adapted to prevent that moist contact with the mass of the earth which is essential to the object in view. Mr. Preece has drawn attention to a very similar case at Lydney, in North Monmouthshire, where the hollow of an iron gas tube, intended to protect the church, was inserted into the substance of a loose stone that was itself imbedded on dry pavement. One of the most sublime instances of this form, not merely of superfluous but of actually dangerous care, came under the author's own observation a few years ago, when he found in the case of a church in Norfolk, which was injured by lightning, although the tower was furnished with an apparently sufficient conductor, that the metallic rod was carried through the necks of glass bottles wherever it was attached to the masonry, and that the system of precaution was finally consummated at the base by putting the bottom of the rod into a glass bottle buried in the dry earth. But a few months since, the author undertook to see the protection of the residence of a friend in the neighborhood of Kensington Gardens, in which an exceptionally lofty house, even for that aspiring neighborhood, had to be defended. A sufficient copper rope was brought down from an iron balustrade that surrounded the summit of the roof, but it so chanced that this was left lying at the lower end on the stone pavement of a sunk basement floor, before the permanent earth contacts had been established, and that a thunderstorm suddenly burst over the neighborhood while the system of protection was left in that unfinished state. The head of the household, in the absence of his scientific adviser, was, however, equal to the emergency. He had the bottom of the rope carefully coiled away into the interior of a wooden pail, determined, most probably, that if the lightning did come down the rope, it should at any rate be kept in the pail until it could be carried away by some competent hand. In one very instructive instance, a house in Natal, which had been furnished with one of the author's galvanized wire ropes for a conductor, but not under his personal superintendence, was injured by lightning. The house was a low-hipped structure, of one story. The rope had been brought from the top roof ridge, which was of metal, along one of the hip angles, then down a corner post, and buried in the ground. The lightning, however, had perversely preferred to go down an opposite hip, where there was, so far, a metal road, and had then leaped through the wall, taking some iron sash weights of a window by the way, and shattering the brick work and doing other damage in its course. The author went down, as soon as he had heard of this accident, to investigate its cause; and the cause was simply this: The lightning conductor had been plunged into a tract of dry sand at the corner of the house. But at the other corner, by which the lightning had effected its own escape to the ground, was an old pool of water that had been filled up with earth,

but was still saturated with moisture, and still connected with ramifications of infiltrated soil. In this case the lightning, when it struck the roof of the house, had divided itself between the two routes which were offered to it, the conductor and the dry sand contact of insufficient area, and the wall, with its stepping stones of sash weights, and its abundant wet contact beneath. The proportion of the discharge which had taken these different routes was determined by the specific resistance of each way, and in the course that involved the leap through the non-conducting wall, the amount which passed was sufficient to produce the destructive disruption which occurred. All competent electrical engineers are now keenly alive to the automatic electrolytic action that is apt to take place in the earth contacts of a lightning conductor, and urge that it is not enough merely to construct an efficient lightning conductor in all its essential particulars, but that the arrangements must be examined from time to time, to make sure that no derangement has taken place. Such examination may readily be effected by making short circuits through the conductor with the wire of a galvanometer, so as to prove by the movements of the needle that the electric path is efficiently clear.

From the instant that an earth contact is established for a lightning conductor, destructive change of the surfaces of contact begins, and, sooner or later, the power of the conductor is materially impaired from this cause. This action, known as the electrolytic disintegration, requires to be constantly watched, beyond all else, and all the more because it proceeds in a region where the conductor is removed from observation by the eye, and it is most fortunate that such watching may be most efficiently and satisfactorily accomplished by so ready and convenient a means as the employment of the galvanometer. M. Wilfred de Fonvielle has indeed proposed that every lightning conductor should have an arrangement of a short circuit wire with the galvanometer attached permanently to it, in a form which he terms *Le Controleur des Paratonnerres*, and which is so designed as to be always ready for the eye of the observer. The author was once very near indeed so furnishing, at his own cost, a proof of the material need of some test and evidence of this character. He had supplied his own residence in the capital of Natal with one of his galvanized iron ropes, with the zinc tube and brush so demonstratively displayed above as to be a constant object of observation and remark to his compatriots and neighbors. The finial was placed so as to be a sort of advertisement of the enlightened practice of the owner of the house, and a standing reproof to the negligence of those who would not follow so excellent an example. The earth contact was very efficiently made, by carrying the rope along the muddy bottom of one of the streams of constantly running water that, in the old Dutch settlements of South Africa, are always found fringing the streets; and during many very severe thunderstorms the author sat in his easy chair, priding himself on the completeness of his arrangements. He subsequently, however, by mere accident, made the astounding discovery that for a considerable length of time the tail of his lightning rope had not been trailed in the wet mud, but was carefully packed away along a stretch of dry ground, under the shelter of a thick-set hedge, that served effectually to conceal its presence there. On some unhappy occasion, when the author was away, the water-courses had been undergoing cleansing and repair by the civic authorities, and the workmen, finding the metal rope in the mud, had taken considerable pains to pack it away in the drier and cleaner place in which it was ultimately discovered. If any accident from lightning had in the meantime occurred to the house, this case would certainly have lived in the annals of Natal, for a couple of centuries at least, as a remarkable proof of the inefficacy of lightning-rods, and the great lightning doctor himself would have been held to have brought down the vengeance of the clouds upon his own ignorance and presumption.

The French electricians have contrived a very excellent expedient for making an efficient earth contact. They construct a stout harrow of galvanized iron, with recurved teeth, connect this carefully with the end of the cable or rod, and then bury it, imbedded in a mass of coke, in moist earth. The cable or rod

is conducted to a suitable site for this terminal in channels of curved tiles, well filled with broken coke, or even sealed up in leaden tubes, if there are ammoniacal vapors to be encountered by the way. M. Callaud has a still more ingenious and admirable plan of effecting this purpose. He hangs at the bottom of the cable a galvanized iron grapnel, with four upturned and four down-curved teeth, and entangles these within a basket of netted wire, and then packs in this basket with fragments of coke; and the basket, coke, and grapnel are afterwards sunk into a pit or well, or buried deep in moist earth. M. Callaud prefers coke to charcoal, on account of its greater porosity and accessibility to moisture; and he has made some careful experiments to satisfy himself of the size which this earth terminal should have. According to the experiments of M. Pouillet and M. Ed. Becquerel, pure water conducts the electrical force 6,754 million times less freely than copper, and therefore, for free transmission, the earth contact, if effected by pure water, should have 6,754 million times the area of the main conducting cable or rod. This theoretical argument is, however, very materially affected by the fact that the water in the earth contains conducting principles of considerable power, and by other analogous considerations; and an earth contact of 1,000 square metres (1,196 square yards) has been fixed by the best French authorities as sufficient for all practical purposes for a conductor of copper, that is, one centimetre (four-tenths of an inch) square. M. Callaud calculates that in order to accomplish this purpose his earth-basket must contain one hectolitre (two bushels and eight-tenths) of broken coke. In order that a lightning rod may perform its work perfectly, it is obvious that there must not be any greater resistance to the passage of the electrical discharge at its earth-outlet than there is in the rod, or main channel of the discharge. Very commonly in badly-arranged lightning-rods, it is found that there is ten thousand times more resistance at the outlet into the earth than there is in the main rod of the conductor. When this altogether excellent expedient of M. Callaud's cannot be adopted, a bore, four or five inches in diameter, should be sunk sixteen or twenty feet into damp soil, into which the cable should be inserted, and then the bore should be filled round the cable with broken coke, and the whole be firmly rammed down; or radiating trenches should be cut as deep as possible in the ground, and corresponding branches from the cable be then packed into these with an investment of broken coke. M. Francisque Michel gives an unqualified approval to the attachments of the lower terminal of the cable to iron-service-pipes, whether of water or gas, in towns.

In Gay-Lussac's report to the French Academy of Sciences, in 1823, it was held that all large metallic masses contained in any building should be brought into metallic communication with the main system of conductors, and that there was no need whatever for the employment of insulating supports in attaching the lightning rod to the structures that it is intended to defend. These conclusions of Gay-Lussac's have been generally acted upon since his time, and no very marked case has ever occurred to stamp the practice that has been adopted in these particulars as radically wrong. In my own practice, in the colony of Natal, I have almost invariably acted upon them, and no single instance of insufficiency of protection has ever come under my notice in consequence of the arrangement. The point is, however, one upon which there is now some difference of opinion in high quarters. M. Callaud, for instance, in his recently-printed treatise on the Paratonnerre, insists upon the adoption of insulating supports for the rod, and unconditionally condemns the electrical communication of the rod with the metallic masses contained within the building; and he states in one part of that work that M. Pouillet has to some extent given in his adhesion to these revolutionary views. M. Francisque Michel, on the other hand, upon a full review of all M. Callaud's arguments, maintains the old doctrine that the conductor may safely be attached to the masonry of the building by ordinary staples or holdfasts, or any convenient way, and that insulating supports are of no use whatever, and that all masses of metal contained in a building should, as a general rule, be metallically connected with the main line of the conductor.

Professor Melsens, of the Royal Academy of Belgium, one of the highest Belgian authorities, contends, upon experimental grounds, that the well-known laws of derived electrical currents apply with equal force to the transmissions of electrical force of high tension, and that scattered masses of metal in any building should be metallically connected with the conductor by closed circuits constituted by contacts with two distinct points of the rod. This divergence of view among high authorities is of notable import, because it is virtually the only material difference of practice that is encountered in the treatment of this subject by well qualified scientific men, and it may therefore be very readily admitted to be an affair that yet requires a more searching investigation, and further severe question by observation and experiment. In the meantime it is of some importance that the exact bearing of the doctrine advocated by M. Callaud should be understood.

In illustration of his argument M. Callaud takes the case of an iron balcony supported in front of the window of a house at some elevation from the ground, and considers the possible result to living men and women contained in this balcony at the time of a severe thunderstorm, accordingly as the balcony is, or is not, electrically connected with an efficient lightning rod. He argues, if the balcony is connected with a lightning rod, a living person standing upon it, or leaning against its rail, is very much more likely to be struck by a discharge of lightning, than if the balcony had no such connection. In the former case, the living body is likely to be made a stepping-stone for the lightning on its way to the rod. He holds that in the case of a lightning stroke the chances are a hundred to one that a lightning rod is struck in preference to any part of a building, that if the conductor is faulty in any particular, and scattered metallic masses are connected to it, this is tantamount to attaching the hundred chances of danger to the metallic masses and to living people placed near them. He says, in effect, a satisfactory and perfect lightning rod should be so placed that it efficiently protects every part of the structure it is attached to, and that if it does this no scattered mass of metal within the building can possibly be struck by a discharge. Therefore, connection of the rod with scattered masses of metal is superfluous and useless where the rod is efficient and perfect in itself, and objectionable and dangerous when the rod is not in an efficiently acting condition. And perhaps the greatest force of this argument falls upon a fact which is very earnestly pressed by M. Callaud, that a lightning rod is a merely passive piece of mechanism, which does not give visible or palpable signs of its own derangement, like a clock, but which may furnish fatal proof of its imperfection too late, by killing the person who places unmerited and undue trust in its efficiency and excellence. M. Callaud remarks with some force: "Lightning cannot strike a structure that is well protected. If the lightning finds at the side of the Paratonnerre an electrical conductor that is superior to itself, the structure is then inefficiently defended. A Paratonnerre ought to dominate, to cover, to protect, a building, in all its parts, and in all its details, or it is better away." The gist of the whole matter, therefore, is, take care that your conductor is perfect and efficient in all its parts, and that it is in every sense adequate to the work that it is required to do, whatever may be the size of the building, and then it becomes a matter of small moment whether scattered masses of metal comprised in the building are connected with the rod or are not connected, and whether the rod is connected to the building by insulating or by non-insulating supports. M. Callaud's conclusion, however, (and it is the one upon which he states that M. Pouillet has given in his adhesion), is substantially, "Connect any masses of metal with the Paratonnerre that are of necessity removed from the occasional close presence of living people, but on no account ever connect such masses with the Paratonnerre when they may at any time have living people in their close neighborhood." Pending further investigation of this very interesting point, there can be no doubt that this distinction is a prudent and a safe one to be adopted in practice, and that it is more prudent and more required in proportion to the insufficiency of the arrangements of the conductor. Conducting masses which are connected

with the earth by less readily conducting substances occasionally give rise to a curious effect, which is techinally known as the return-shock, and which is altogether a result of inductive action. When a powerfully charged electric comes within a moderate distance of them, an electrical charge of an opposite character is drawn into them by induction, but this secondary charge escapes back towards the earth the instant the inducing tension is removed. The production and character of this return shock, caused by inductive action, admits of very complete illustration by electrical apparatus. An insulated conductor of long cylindrical form, but with its glass supports only half the length of the glass pillar of a prime conductor of an electrical machine, may be placed parallel with the prime conductor, but about an inch away. The secondary conductor is then to be raised to the same height as the prime conductor, by fixing its glass pillar upon the top of a pillar of wood, a fine wire being carried from the metal cylinder to the wood. A wire is then also to be carried from the secondary conductor to the earth, but is to be so arranged that a small gap may be left in some convenient part of its course. When the prime conductor is charged positively by the machine, the positive electricity of the secondary conductor is inductively driven out through the wire and the wooden pillar to the earth, and the conductor itself remains negatively charged. But when the working of the machine is stopped, and the prime conductor is deprived of its positive charge by a touch of the finger, the negative charge in the secondary conductor is also set free from its condition of inductively maintained constraint, and positive electricity leaps back from the earth to restore its proper balance and saturation, and as it does so is seen passing as a spark through the gap in the earth-wire, because that gap affords less resistance to the passage of electricity of tension than the supporting pillar of wood. If a little gun-cotton, or some other suitable inflammable substance is placed in the gap, it is fired by the spark at the instant of the discharge. Professor Tyndall, in his lectures at the Royal Institution, shows the production of this sympathetic inductive discharge in a very magnificent form. He has a flat coil of copper wire imbedded in a mass of insulating resin, through which he can pass the discharge of the powerful battery of the institution, consisting of fifteen Leyden jars; and he has also a second flat coil similar to the first, which he can place parallel to it and about an eighth of an inch away, the two ends of the second coil being connected with a wire presenting a small gap of continuity. When the discharge of the battery is passed through the first coil a powerful sympathetic discharge rushes at the same instant through the secondary coil, and makes itself manifest by a bright flash and a loud snap in the gap of the connecting wire. The discharge of an electric cloud in this way not uncommonly produces a number of sympathetic minor discharges from neighboring bodies. The induced discharge is sometimes quite strong enough to produce mechanical mischief in resisting bodies that lie in its path. The shocks experienced by living people on the instant of a discharge of lightning, without fatal results, are generally of this character. It was to meet the case of these incidental induced charges, and the consequent "return shocks," that the expedient of connecting scattered masses of metal with the conductor was originally devised. The return shock resulting from a limited inductive disturbance may be strong enough in some circumstances to cause death by the mere arrest of the vital action of the nerve structures through which it passes, without leaving behind it any trace of mechanical violence, such as is generally produced by the true lightning stroke.

The old practice of protecting buildings from lightning consisted in erecting rods of metal upon wooden frames, near to, but not in actual contact with, the walls of the house. When the author of this article first visited Natal, in 1857, the houses in the two principal towns, that were defended at all, had independent conductors of this class, of the rudest possible kind, erected by the side of the one-storied houses upon ungainly wooden frames. The conductor was composed of an iron rod, joined in three lengths, and rudely pointed above, and it was made of three different pieces —a comparatively thick one below, and

a comparatively thin one at the top. This practice was primarily based upon an investigation which was conceived to demonstrate that all structures lying within a conical space, which had the conductor itself for its height and a breadth for its base equal to four times the height of the conductor, were safe. This estimate gives a fair approximation to a truth, but it is by no means absolute, and must not be empirically relied upon. It, however, furnishes a very good indication of the way in which the upper termination, or terminations, of the rod must be arranged. The terminal point should go some considerable distance above the housetops, and then if any projecting parts of the house extend beyond the surface of a line having, perhaps, a somewhat more acute figure than the one which has been named, other subsidiary points must be reared up from the line of the conductor above such conical slopes. Mr. Preece, in his paper, considers that the lightning conductor should only be held to afford absolute protection within a conical space in which the base is as large again as the height of the line. When, however, the general idea of the limits of this lateral protection is once clearly conceived, it becomes very easy, indeed, to render the arrangements of the upper terminals perfect for any individual case. It is only necessary that all prominent masses of metal shall be connected with the system of metallic communication, and that an addition branch of the system of defence shall be carried out whenever outlying parts of the structure get near to the conical limit of protection. This is virtually what has been done in the case of the Hotel de Ville, at Brussels, with its terminal of 264 points.

When Sir William Snow Harris, now some years ago, turned his attention to the protection of ships from lightning, he devised a plan of making the lightning conductor a part of the original design and essential construction of the ship. Now all large and well-contrived vessels are always built with the lightning rod included in their structure. It is almost incredible that up to this time the same course has not been taken with houses. It is hard to understand why lightning conductors should be objects of exceptional luxury, and rain pipes objects of daily need, and the more so when rain pipes themselves can be so easily turned by a little forethought and mechanical ingenuity into lightning conductors of the most efficient character; they only need that their joints shall be made mechanically continuous, that their earth contacts shall be perfected, that all masses of metal, with perhaps the limitation that is contended for by M. Callaud, shall be brought into metallic communication with them, and that metal terminals shall be distributed from them to the roofs above upon the principle that has been explained. Mr. Preece has thrown out one very excellent suggestion which well deserves further thought; it is to the effect that metal ventilating pipes carried up from the sewers over the roof of the house may advantageously be made part of the arrangements for protection against lightning. The familiar case of the Monument of London is continually adduced as a proof of the readiness with which the accidental features of a building may be turned to account for this purpose. The metallic emblems of flame at the top of the column are continuously connected with the ground by means of a very thick balustrade of iron that runs as a hand-rail down the stairs; the structure is 200 feet high, and towers above all neighboring buildings, and yet it has now stood within three years of two centuries without ever having been injuriously touched by the lightning.

It was conceived, until recently, that St. Paul's Cathedral had been efficiently protected in some similar way by the arrangement of water-pipes, and some supplementing of them by metallic rods, added by a Committee of the Royal Society some 120 years ago. Mr. Faulkner, of Manchester, however, found, in a careful examination made subsequently to 1872, that the system had become entirely inefficient for the purpose for which it was intended, by the formation of thick incrustation of rust on the contact surface of the rods, and by the interpolation of blocks of dry granite, some nine inches thick, in places, into the actual line of electrical conduction. The entire building has now been most efficiently protected, under the skilful direction of Mr. Faulkner, by carrying eight

octagonal half-inch ropes of common wire from the Cross, Ball and Golden-Gallery through the metal-work of the roof of the dome, and through the metal work and rainfalls of the lower parts of the building to the sewers, where the conducting strands terminate in copper plates pegged into the moist earth. In carrying out this work every important metallic portion of the building was separately tested by the galvanometer, to make sure that the electrical communication with the earth was virtually and substantially clear. The galvanometer was first made into a circuit with a metallic gas-pipe; and then the circuit was opened out, so that earth was made in one direction through the gas-pipe, and in the other through the metallic portion of the building for the time under examniation; and the test was not considered satisfactory until the deflections of the galvanometer were the same under both alternatives. In arranging methodical architectural plans of this kind it must always be carefully borne in mind that small gas-pipes of easily fusible metal must on no account form part of the connecting lines of conducting circuit. Gas-pipes are most easily fused by a stroke of lightning, and when they are so fused the gas which escapes from the extemporized orifice is invariably set light to.

One point which was expressly urged by Mr. Preece and by Captain Douglas Galton in the discussion of Mr. Preece's paper at the Society of Telegraph Engineers, should be most carefully kept in view in any structural plan matured for the protection of buildings, namely, the including of all fireplaces or stoves, and soot-blackened chimneys in the system of connected construction. To adopt Mr. Preece's own statement of this need: "It must not be forgotten that a chimney lined with a thick layer of soot, up which a current of heated air and volumes of smoke are ascending, and terminated by a mass of metal (the grate), is an excellent but dangerous conductor, for it ends in the room, and not in the earth."

Since the first preparation of this paper, two pamphlets by Messrs. Gray & Son, of Limehouse, have come into the hands of the author, which are valuable and interesting on account of the details which they contain of a considerable series of instances of damage from lightning. Mr. W. J. Gray, of this firm, was originally concerned with Sir Wm. Snow Harris in perfecting his plan for protecting ships, and obviously possesses a large amount of practical information in regard to accidents that have occurred. Space now only serves to say that the Messrs. Gray endorse the practice of connecting all metallic masses in a structure with the main line of conduction, and especially urge the surrounding of all prominent objects, such as the tops of tall chimneys and church towers, with continuous bands of copper brought down into direct connection with the discharging rod.

The great length to which this paper has already extended itself alone prevents some allusion being here made to the views of Professor Zenger, of Prague, who advocates the use of circular zone-like or ring-shaped conductors, embracing within their span the objects which are to be defended from injury.

There is no sufficient ground for the popular idea that accidents from lightning are of such rare occurrence that it is scarcely worth while to incur the trouble and cost which artificial protection involves. The figures of the statistician prove that accidents are very frequent indeed. The Escurial in Spain has been set fire to four times by lightning in less than three centuries. As many as 1,308 persons were ascertained to be killed by lightning in France between 1835 and 1852. Some time ago the mean number of deaths from lightning in each year was marked at 3 in Belgium; 9 in Sweden; 22 in England; 50 in the United States of America; and 95 in France. M. D'Abbadié records the destruction of two thousand sheep by a single discharge of lightning. Mr. Preece tells of 897 telegraph instruments injured by lightning in the first six months of 1872 in a staff of 9,475 instruments. Mr. G. J. Symons, one of the secretaries of the Meteorological Society, has given, as the list of accidents that he had ascertained to have happened during two severe storms in June, 1872; 10 deaths and 15 cases of injury to human beings; 60 houses struck and 15 burned down; and 23 horses or cattle, and 99 sheep killed.

It need scarcely be said that many accidents also occur every year from lightning, over and above those which get publicly spoken of or placed on record. In large towns damage to property is more frequent than destruction of human life, but in the open country destruction of life is the more frequent occurrence. In the face of figures like these, and of the fact of the slowness of man to avail himself of the ready defence which science places at his command, unfortunate humanity certainly stands very much in need of the consolation which the physiologist affords when he tells us that all danger from lightning is past when the flash of the electrical discharge is seen, and when he further states that when men are killed by lightning they are dead before they have time to know anything about the fact, or indeed to be conscious of the fatal blow; a conclusion by the way that is strikingly corroborated by an unintentional experience of Professor Tyndall's, who upon one occasion passed the full charge of the Leyden jar battery of the Royal Institution, by accident, through him, and was perfectly unconscious of any shock. It is something, at any rate, to have this comfortable assurance when the sense of neglected opportunity comes over the mind in an exposed situation and in an unprotected house during a severe thunderstorm. But it is humbly submitted, as an appropriate last word of this paper, that to men of well-regulated minds a good lightning conductor may, in such emergency, be found to be an even greater satisfaction and comfort.

THE IRON AND STEEL INSTITUTE.

Address of the President, Mr. W. MENELAUS.

Abstract from "The Engineer."

My first duty is to thank you for the very high honor which you have conferred upon me in electing me to fill the office of President of the Iron and Steel Institute. As an iron maker my mission has been to bring into profitable use the valuable inventions of Bessemer, Siemens, and others, and to apply the scientific research of men like Mr. Bell to the improvement of old and new processes.

So much has been said, and well said, by my predecessors about the history, the position and the prospects of English iron making, that I propose on this occasion to confine my remarks mostly to the manufacture of wrought iron and steel, and the application of the latter to constructive purposes. For the conversion of pig into wrought iron, the rotary puddling machine, in one or other of its forms, has occupied the attention of iron makers for many years, and various attempts have been made from time to time to perfect the machine. When, under the auspices of this Institute, the Danks machine was introduced into this country, success seemed certain; several machines were erected, mostly at and near Middlesborough, but they seemed to have failed, chiefly from defects in mechanical construction. These defects have, I am told, been rectified, and several important improvements have been made in the construction and mode of working the machines. To Messrs. Hopkins, Gilkes & Co., is due the credit of having first introduced and practically tested these machines in England. The Erimus Company followed, and erected extensive works, in which the Danks machines alone are used. Certain difficulties were met with, and no doubt, for a time, some disappointment was felt; how these difficulties were met and overcome is fully explained in an interesting communication from Mr. John A. Jones, which I will read:

A year ago the writer stated in London, what were at that time considered to be the chief drawbacks to the success of rotary puddling. They were stated to be the education of the men and the removal of prejudice from amongst them; the difficulty with the fettling of the furnace, and the mechan-

ical weakness of the Danks machine. It was quite evident that unless the company could procure a certain quantity of iron from each machine in a given time and in a regular manner, rotary puddling could not favorably compete with hand puddling, so far as the cost of puddled iron was concerned. The obstacles were in chief as stated above, and to the removal of these the company devoted their attention. The education of men, which includes the change from a positive state of indifference to that of active assistance, has given more trouble and anxiety than was anticipated; and to this day we have not received that active co-operation from the men which is necessary to the complete success of rotary puddling. At the same time much progress has been made in that direction, and it is earnestly hoped that in a short period we shall receive that assistance which will enable us to do better than has hitherto been done. The fettling of the furnace, and the materials used for the same, are no longer questions of difficulty, and in this respect we have no drawback. We line the furnace after each heat with best tap, pottery mine, purple ore, and Spanish ore; suitable proportions are mixed in a grinding mill, and then used in the furnaces. Fettling can be procured suitable to any district where the difference in the quality of the pig iron mostly necessitates a variation in the fettling ingredients. With regard to the mechanical imperfections of the Danks machines, they have been of a serious character. The repairs have been very costly, and the loss of output, by reason of frequent stoppage, has affected the cost of production most unfavorably. It became apparent that unless the mechanical construction of the furnace was such as to insure regularity of work, it was hopeless to expect satisfactory results; and the attention of the directors was devoted to this necessity. It was at last agreed that new furnaces of a different construction should be adopted, and to that end one was erected as an experimental furnace. This furnace has been at work for nearly two months. It is a double-case wrought iron furnace, hooped with steel, and is water-jacketed. There is a constant flow of water to and from the water space, and the water at the outlet pipe is kept at from 80 deg. to 100 deg. Fah. — in fact, perfectly cool. This double-cased furnace has maintained its mechanical accuracy, which it is almost impossible that a single-cased furnace can do, owing to the effects of expansion and contraction. The firing of the new furnace is done in the usual manner. It will not be necessary for me to describe in detail the improvements of this machine; let it suffice that it has been designed and constructed, after all the weak points of its fore-runner have been carefully considered. The directors are so satisfied with the work done by this machine that they have ordered five more, and six sets of new engines to drive them. In designing the engines the same amount of care has been taken. They are over-head double-cylindered engines; the wearing parts have been carefully designed, and nothing in strength or in the detail is left unprovided for, so as to insure continuous and satisfactory working.

In manufacturing puddled bars at the Erimus Ironworks, the pig iron is first melted and refined in one of Thomas' cupolas. The refining is done during the smelting process, and is accomplished by simply mixing scrap iron and ore in the charges. The perceptible effect it has upon the iron is that where the charge is exclusively of No. 4 forge grey pig, the fracture becomes that of white or refined iron. The chemical effect is that a portion of the silicon and phosphorus is removed, and it is to this end that the refining is done, so that there will be as little action as possible upon the lining of the furnace. The effect of using refined iron is very marked. We do not perceive any melting out of fettling *per se*; but what is used is reduced, and thus adds to the yield. Again, the refining of the iron does not necessitate the fettling of the furnace so often, whereby much economy is effected in the fettling used, and in the time which is devoted to puddling. We charge entirely with melted and refined iron, and the weight of our present charge is 14 cwt., which, when the new furnaces are erected, will be increased to a ton. The Cleveland forge iron, which is almost exclusively made from a foundry burden, is very silicious. It

holds from 2 to 3 per cent. of silicon. It is obvious, therefore, what an evil effect this pig iron has upon the fettling; and a portion of this is removed, as is stated, by refining. In Cleveland scarcely any grey forge is made from a forge burden, but it is derived from an attempt at foundry iron, and the finished iron-making suffers severely from this. No heat takes more than thirty-five minutes to puddle. The heat is removed in a single ball, and squeezed or shaped into a piece about 14 ft. long by 15 in. diameter. It is then cut up at the same heat, and taken to reheating furnaces, where it is reheated, hammered, and rolled into bars. The Erimus Company are now making angles, bulbs, bars, and tees, with no other iron than Cleveland. Three relays of men are employed at the machines, and work eight hour shifts. It is expected that each furnace will work six heats in the eight hours, and this is regularly done unless some break-down or accident interferes; and with the old machines those breakdowns are unfortunately only too frequent. At the present time the company are working six furnaces, and they average nearly 300 tons per week of puddled bar, thus giving an output of 50 tons per furnace per week. The present consumption of coal is for actual puddling $9\frac{1}{2}$ cwt. to the ton of bars. Of fettling (half bought and half from first heating or mill furnaces) 9 cwt. to the ton of bars. The yield of bar from pig is 20 cwt. of pig to 20 cwt. of bars. The whole quantity of coal used to the ton of bars, including reheating, is under 20 cwt. The price we pay the puddlers is at present 3s. $2\frac{4}{10}$d. per ton long weight, they paying their own under-hands. The whole wages of every kind, including cupola-refining and re-heating, is under 20s. per ton of bars. The question now arises—Are we satisfied with a production of 300 tons per week from six furnaces; and is there any prospect of increasing that quantity? The answer is—We are not satisfied; and there is every prospect of the quantity being increased to 500 tons per week from six furnaces. To this end new machines and engines are ordered, capable of taking one ton charges; and the tools are being remodeled to handle the heavier charges. The experiment of working a ton charge has frequently been made, and the time required for puddling never exceeds forty minutes. The number of heats will be the same as at present—viz., six in eight hours; and it is simply by the increase of the weight of the charge that the quantity will be raised from 300 to 500 tons. The actual puddling of the six heats will take up four hours, leaving the other four hours for fettling, repairing, cleaning grate-bars, etc. We find that it takes the same coal to puddle a ton as to puddle 14 cwt., and as the time consumed in charging, drawing, fettling, and squeezing, will be the same as at present, it is obvious that the increase of the charge to a ton is the proper course. We have no doubt that we shall be able to bring the consumption of coal for puddling down to 7 cwt. to the ton of bars; and the whole of the coal consumed in the puddling department to 15 cwt., and we anticipate that the wages will not exceed 15s. on the ton of bars, which will include all labor charges in the puddling department. The new furnace at the Erimus Works, when worked experimentally, gives results much better than are stated here. The foregoing figures give the average results of our working in a regular manner.

(Signed) J. A. Jones,
Managing Director.
The Erimus Company Limited.

The Erimus Ironworks.

Make at Forge, four weeks ending March 27th, 1875.

	Tons.	cwt.	qr.	lb.
Week ending 6th of March; number of furnaces, 5....................	193	2	1	15
Week ending 13th of March; number of furnaces, 6....................	282	7	1	5
Week ending 20th of March; number of furnaces, 6....................	298	0	3	0
Week ending 27th of March; number of furnaces, 6....................	275	5	2	10
	1048	16	0	0

In thirty-six working days of twelve hours.

Coals consumed for Puddling alone, four weeks ending March 27th.

	Tons.	cwt.	qr.	lb.
Week ending 6th March	92	5	0	0
" 13th "	116	10	0	0
" 20th "	141	1	2	0
" 27th "	124	8	0	0
	474	4	2	0
		cwt.	qr.	lb.
Coal to a ton of bars on puddling alone		9	0	6

Certified to be corrcct, and taken from our pay books. John A. Todd, Pay Clerk.
J. A. Jones.

The members of this Institute have taken such a deep interest in the Danks method of puddling, that I believe you will all be pleased to know the precise position in which it now stands, and we ought to be very much obliged to Mr. Jones for the very explicit statements which you have just heard. Mr. Heath, with his usual enterprise, was one of the first to take up in earnest the Danks system of puddling. Mr. Heath informs me that he has had six Danks furnaces at work for some time, and has four additional furnaces ready for work. He is rolling from Danks blooms, in the ordinary forge rolls, 16 in. bars, 24 ft. long. Mr. Heath states that he is making these bars more cheaply than by the old puddling process, to say nothing of the saving in waste in cutting up long bars as compared with bars one-fourth the length. Mr. Crampton, who has made a long series of experiments on mechanical puddling, having been at work on the subject over five years, has produced some very excellent results as to quality of metal; and he assures me that his experimental machine at Woolwich is workiug very economically, and that it will bear the test of continuous work; to use his own language, "The furnace is fitted to stand the rough usage to which such a machine must be subjected in ordinary iron works, and it involves a minimum expense for wear and tear, and for general repairs."

Sir John Alleyne has also worked at this problem of mechanical puddling. He is experimenting with the Siemens rotator and also with a modification of Maudslay's machine. Mr. Reynold Alleyne thus describes the latter machine as modified by his father: "We are now working my father's machine with Siemens' gas furnace, and also heated by direct combustion in the ordinary way. The machine consists of a pan, which rotates on a vertical axis, and the puddler, which is fixed overhead, and which works the rabble to and fro at right angles to the front of the furnace. When the heat is ready to ball up, the puddler is stopped, but the pan continues to revolve. The work of balling is done at the door, and it is never necessary to reach across the furnace. In the gas furnace we charge five heats of 6 cwt. per shift. The waste is 2½ to 3 per cent. The waste in the direct combustion furnace, with the same charges, is 10 per cent.; showing the advantage of using gas in place of solid fuel. The two furnaces are worked by one puddler each, and a boy to look after the machinery of both furnaces." Sir John himself expresses an opinion in favor of the pan, or "soup plate," as he calls it, heated by Siemens' gas furnace." At our annual general meeting in May of last year, the Pernot furnace was described. The furnace is the revolving pan with the axis inclined, as invented by Maudslay; but M. Pernot has made an important improvement on Maudslay's furnace. He has mounted the revolving pan on a carriage on wheels, and it can be withdrawn from the puddling chamber for repairs. Mr. Snelus, who has just returned from a tour through the French works, informed me that he saw three Pernot's puddling furnaces at work at Messrs. Petin Gaudet's works. They were working one ton charges of iron, mostly white, and each charge produced 18 cwt. of puddled bars. The fuel was slack coal, of which they use 14 cwt. to the ton of puddled bars. The fans are fettled with Motka iron ore, about 2½ cwt. being used to the ton of iron made. Each furnace produces about 4 tons of puddled bars in twelve hours. Two puddlers at each

furnace ball up the iron. Mr. Snelus adds that the furnaces have been at work some time, and that they seemed in fair working condition. In the manufacture of steel, we are making in England, by the Bessemer process alone, ten thousand tons per week, and the production is rapidly increasing. Various mechanical improvements have been made, which enable us to turn out larger quantities. In some cases as much as one thousand tons per week has been made from a pair of converters. When Mr. Bessemer first designed his steel-making plant, his idea was to run the iron direct from the blast furnace into the converters. His first apparatus, on a large scale, was erected at Dowlais, where it was put down in front of a blast furnace, and the iron was run direct from the furnace. The experiment, for reasons quite independent of the mode of charging the converter, was not successful; nevertheless, we in England have ever since been content, for no sound reasons, I think, to melt down the pig iron at considerable cost, instead of running it straight from the furnace. In most cases in France, and in some other countries, the iron is run direct from the furnaces; and I see no reason why in England we should not revert to Mr. Bessemer's original plan, and so save all the cost and waste of melting. Of course, it will require careful management at the blast furnaces; but with our pure fuel, excellent ores, and with a plentiful supply of pure foreign ores as a mixture, I see no difficulty in carrying out this economy in the production of Bessemer metal. Mr. Bessemer informs me that, under his advice, in one of our leading steel works they are about to run the iron direct from the furnace; to use his own language, "They will use my process of further carburising 20 tons of metal at a time in a hot vessel, mounted on wheels and running on rails to the converters; the metal will keep hot for several hours in this vessel. Less carburetted metal may be made in the blast furnace, and the necessary quantity of carbon added at almost no cost." Another member of our Institute, Dr. Siemens, has worked out, in a different way, the same problem, with much success. The idea of producing steel by melting together cast and wrought iron, or cast iron and ores, in suitable proportions, is, of course, old, but it was not until Mr. Siemens brought his scientific and practical knowledge—and a no less wonderful amount of perseverance—to bear on the subject, that the mode of making steel, known as the "Siemens-Martin process," was perfected. The most important element in the successful accomplishment of the Siemens-Martin process is unquestionably the "Siemens, or regenerative, gas furnace." By its means, any degree of heat, even to the fusing point of the most refractory materials, can be obtained economically and without resorting to air-blast or cutting draughts, and these conditions are indispensable where we have to deal with a bath of mild steel, exposed to the surface action of the flame. An adequate idea of the elevated temperature obtainable in these furnaces may be formed by considering that near the end of each operation the furnace contains from five to six tons of almost chemically pure iron in a state of perfect fluidity, beneath a covering of slag, several inches thick. Mr. Siemens estimates this temperature at 2200 Cent. Mr. Siemens states that he is now erecting furnaces of 10 tons capacity, which will be capable of producing 20 tons of steel in twenty-four hours if pig and ore be used, and 30 tons if pig and scrap be employed. The steel made by the Siemens-Martin process is used for all the purposes to which soft steel is commonly applied. It is used in England for casting screw propellers, and for various other high-class steel castings. At Creusot a mild steel is produced by this process containing only 10 per cent. of carbon, which is used for piston rods, and other parts of engines, for boiler-plates, and, more recently, for shipbuilding. As we know, Mr. Siemens has for some years been engaged on a method for producing malleable metal direct from the ore. The process consists in treating ore with reducing materials in a rotary furnace, under the influence of a reducing atmosphere, accompanied by the intense heat produced by his regenerative gas furnace. His object is to produce either bar iron or metal from the bath furnace direct from the ore in one operation, and at a greatly reduced expenditure of fuel; but, although this method has, as I under-

stand, succeeded experimentally, proof is as yet wanting of its practical success on a large scale. M. Pernot has applied Maudslay's revolving pan, not only for puddling, but also for making Siemens-Martin steel. The furnaces produce over ten tons of steel per shift of twelve hours. The waste is said to be 7 per cent., and the consumption of fuel 7 cwt. to the ton of ingots made. The cost of labor is stated to be 4f. per ton. This furnace is worthy of the attention of English steel-makers, and is, I think, destined to play an important part in the manufacture of Siemens-Martin steel. I have said that Mr. Bessemer has given us what may be fairly called a new metal, and a wonderful metal it is; and that, by an entirely different process, Mr. Siemens has enabled us to produce the same metal also at a moderate cost, and with all the excellent qualities of Bessemer metal. For a considerable period I have been engaged in making Bessemer and Siemens-Martin soft steel, and I claim to know something of the excellences of both. Speaking as a manufacturer, I am of opinion that, with our present knowledge, in no other form can iron or steel be produced at the same cost, and of a quality equal to that of the steel made by the Bessemer and Siemens processes. Having a high opinion of the value of the material for constructive purposes, and seeing with how much success it has been applied on our leading railways, and how it has almost completely superseded the old forms of wrought iron, where it has been introduced with skill and a full knowledge of its properties, I wonder, and wonder much, that many of our leading engineers and shipbuilders have ignored this material as if it did not exist; and this in the face of the fact that for years this metal has been used for purposes where only material of the highest quality is admissible, and that it has given, and is giving, so much satisfaction that those men speak of it the most favorably who have used it the most largely. So many distinguished mechanical engineers have used Bessemer steel, that in speaking of their varied experience, I hardly know where to begin. Sir Joseph Whitworth is making from the Bessemer converter some of the finest material known. By his process of compressing the steel while it is in a liquid condition, he produces a quality far superior to anything which can be made by the ordinary methods of treatment. Sir Joseph writes, "During the last twelve months we have been working night and day, principally on guns, cylinders for hydraulic purposes, cylinder linings, torpedoes, etc.; the melting has been by the Bessemer and crucible processes, and we are just about to use the Siemens-Martin process also. The state of my health has prevented us from commencing new works, but we hope to do so before long." This material is as yet too expensive for use in ordinary work, but Sir Joseph has shown that out of the Bessemer converter can be produced, as I have said, some of the finest material known. Mr. Ramsbottom, when at Crewe, began to use Bessemer steel in the construction of locomotives, and for other purposes, and his able successor, Mr. Webb, has greatly distinguished himself by his care in the manufacture of Bessemer and Siemens steel, and by his skillful and spirited application of the metal to almost every purpose, and particularly in cases where material of the very highest quality is indispensable. No man, I think, has done more than Mr. Webb to improve the quality of mild steel, or so much to extend its general use. Mr. Sharp, of Bolton, was one of the first to produce excellent boiler and ship plates of steel, and to make boilers of steel plates. Mr. Sharp tells me that they have made between nine and ten thousand tons of steel plates at Bolton, three-fourths of which have been used in the construction of boilers. He says that steel plates, with a tensile strength of from 30 to 34 tons, are easily and safely worked by experienced men. They have had steel boilers at work for nine years, and they have given perfect satisfaction, and the repairs are light to those compared with iron boilers. Mr. Adamson, whose talent as a mechanical engineer is well known to us all, informs me that in his steam engines, when the choice of materials is left with him, all the principal parts are made of Bessemer steel, and that the results have been most satisfactory. Mr. Adamson states that he has used various kinds of steel in boiler work, but since the introduction of Bessemer steel plates he has

used no other; of this material he has made between six and seven hundred boilers, mostly for high pressures. He is now making a number of steel shell and fire-box boilers, of 7 ft. diameter, to work 80 lb. and 100 lb. pressure per square inch. Mr. Adamson has used mostly steel plates of Barrow make. He says that they are very uniform in quality, and from all causes he has not had to return or set aside more than one plate in a thousand. He describes his method of working steel plates as follows: "A piece is cut off every plate and tested before the plates are accepted; the edges of the plates, when used for boilers, are all planed, the rivet holes are drilled through both plates together, after the plates are bent and in place; in every case double or chain-riveting is adopted." He goes on to say: "In the application of steel plates for fire-boxes, I have experienced the most satisfactory results; there is no blistering, and the plates show great endurance. When boilers have been allowed to run short of water, the plates have bulged or collapsed, but they were never fractured." In this respect, he thinks that steel plates are superior to any iron ever made. Mr. Adamson, like Mr. Sharp, advocates the use of steel of comparatively low tensile strength, from 30 to 32 tons per square inch. Steel of 38 to 40 tons to the inch was found quite unsuitable for boiler work; it was wanting in ductility, and the use of such a material was quickly abandoned. A great deal has been said and written about the want of uniformity in Bessemer steel, but what could be more satisfactory than Mr. Adamson's experience on this head? Messrs. Galloway, of Manchester, who have a large experience in boiler making, and who are noted for the excellence of their work, inform me that when they commenced using Bessemer steel plates, about 1861, the results were not satisfactory, the plates being too hard, but that of late they have used steel plates extensively, and that the conclusion they have come to is that when the annealing is carefully performed the plates are perfectly trustworthy; in fact, in the testing of boilers they now find quite as little trouble with steel plates as with iron ones, if not less. They state further that careful annealing has a most beneficial effect; and they refer to some experiments made for the Manchester Boiler Insurance Company by Mr. Kircaldy on the strength of riveted joints, which conclusively proved that even in the case of wrought iron plates, which are punched, it is advisable to anneal them. With respect to the employment of steel for bridge work, Mr. Maynard, of the Crumlin Viaduct Works, writes: "With regard to the question of employing steel for railway bridges in this country, I may at once say that, practically speaking, steel is excluded from use by the somewhat arbitrary limitation laid down by the Board of Trade—to 5 tons strain per square inch when used in tension, and 4 tons per square inch in compression—no higher strain being allowed whatever may be the quality of the material, and even if steel is used in place of iron. When a girder bridge is required of a trifle over 400 ft. span for a railway it is found that the weight of the iron, etc., necessary for its construction is alone sufficient, without the rolling load of a train, to strain the iron in the most important parts of the structure to very nearly, if not fully, the limit laid down by the Board of Trade—therefore, we make but little progress in large span bridges in this country. Steel has been employed very successfully in some bridges of large span which I have seen in Holland, and elsewhere, whilst in England we adhere to the old rule-of-thumb practice without much chance of improvement. It is obvious that if a material is used that will bear a high strain, it results in a lighter and stronger structure, and I should be glad to employ steel even in small girders, but for the difficulty of getting the Board of Trade to acknowledge its superiority over iron, and to allow a higher strain to be imposed than is adopted for iron." Having given you the results of the experience of some of our leading mechanical engineers as to the value of mild steel for constructive purposes, I have now the pleasure of laying before you the opinion of a man who has earned a world-wide reputation as a shipbuilder, and whose professional advice is sought by the most powerful Governments in Europe; Mr. Reed, the late Chief Constructor of our navy, writes to me as follows: "In reply to

your favor of the 20th, allow me to say that for more than two years past I have been thoroughly satisfied that the production and methods of working steel had reached a point when that material might be extensively and very advantageously used for shipbuilding purposes. I, therefore, designed some very fast war vessels in steel, and obtained some provisional orders for them, but when I came, two years ago, to the question of building, I could not satisfy myself that the proper supplies could be secured under the same conditions and facilities as iron. This was due, however, entirely to the fact that my orders would not have been sufficient alone to justify any large firm in entering systematically upon the production of steel plates and angles for ship purposes. Great progress has been made in this respect since then, and I am now receiving orders for despatch war vessels to be built of steel —boilers and engines as well as vessels— and I am about to build two at Pembroke, and probably to place others for construction in other establishments. It will, therefore, be a very great advantage if in your address you can stimulate the attention or the profession and the trade to the subject, because I am satisfied, that when once a systematic commencement is made there will, henceforth, be no obstruction to the large development of steel for shipbuilding. I say nothing here about the special arrangements which the use of steel for shipbuilding purposes renders necessary, because, although they are unusual and additional, they are such as present no real difficulties to a careful builder." I would also call attention to the somewhat extensive use of steel in the French navy; and, above all, I would point to what the Germans are doing. In Germany there is no want of confidence in the character of steel. Mr. Krupp, who may be called the father of the steel trade, has evinced a wonderful amount of skill in the production of large masses of steel, and in its application to purposes where its strength and ductility are submitted to the most severe tests. Mr. Longsden informs me that they are making at Essen at the present time 14 inch guns of steel, which weigh, when finished, 57½ tons, carrying a shot 9 cwt. 9¼ English miles, using a charge of 210 lb. of gunpowder. They are about to make steel guns of the following capacities and weights—15¾ in. bore, 30 ft. long, weighing 82 tons, using 300 lb. of powder, with a shell of 1,500 lb. weight; guns of 18 in. bore, 32. ft. 6 in. long, weighing 124 tons, using 440 lb. of powder, with a shell of 2,270 lb. weight. Mr. Longston demurely adds, "It is calculated, for the present, that these guns will be heavy enough to destroy any armor a ship can carry." In gloating over the destructive properties of these weapons, he is leaving out of his calculation, perhaps, the flash-of-lightning ships which Mr. Reed is about to build, and which may, under smart management, be able to get out of the way of such a conspicuous object as a shell weighing over a ton, even when fired with about a quarter of a ton of gunpowder. In alluding to the use of high-class steel for guns, I wish it to be understood that I am not seeking to give any opinion as to the superiority of steel over wrought iron for this special purpose. I merely wish to call attention to the fact that in Germany and, I believe, in most continental countries, as also, I may add, by one at least of our most celebrated gunmakers in England, steel is being used for making guns of the heaviest description; and it is well known that these steel guns have stood the most severe tests at proof, and also when put to their more legitimate use. Speaking of guns gives me the opportunity of calling special attention to the wonderful structures in wrought iron now being built up at Woolwich and Elswick. Forgings are made there which for weight and quality of material were never equalled; and the guns, when finished, even if looked at simply as engineering works, reflect credit not only upon the men who produced them, but upon England as a nation. As we are about to have an inquiry as to the merits of these guns, I sincerely hope that it may turn out, as I daresay it will, that those wonderful weapons have not been constructed to load at the wrong end. You will have observed that in speaking of the present position of mechanical puddling, and of the improvements now in progress, I have preferred, for the most part, to use the language in which the information reached me. It was my intention, for the purpose of this address, to make a

tour through all the works of England and France where puddling machinery is in operation. But when I considered that some machines of great promise are still, strictly speaking, in their experimental phase, I felt that, in the circumstances, even a very careful inspection would not enable me, from my own observation, to arrive at perfectly sound conclusions. I therefore thought it better to invite the gentlemen who are so ably, and I think, successfully, working out the problem of mechanical puddling, to give me information as to the results of their experience, and as to the prospects of their various plans. These gentlemen have with the greatest courtesy, furnished all the information that I sought—information which I am sure will be of the greatest interest to the members of this Institute. I have, like many of you, watched with great interest the advance of mechanical puddling; and from the day, long ago, on which I saw Mr. Tooth at work at Stepney until now, I have never for a moment doubted that mechanical puddling would sooner or later be perfected. I think that there is now almost a certainty that this problem, upon which has been expended so much labor and thought, and which has brought to many so much disappointment, will within a short period be fairly solved. I have told you, with the authority of Mr. Bessemer and Mr. Siemens, what improvements they are contemplating in the way of cheapening the production and increasing the make of steel, and I believe that every leading steel maker in England is engaged in devising new modes, or introducing new methods already tried, for increasing and cheapening production and no less for insuring excellence and uniformity of quality. On the question of the applicability of steel to various purposes where it is now used but sparingly or not at all, I have sought the opinions of men whom we all know, most of them being members of this Institute, and all of them holding high rank in their profession; and here again I have preferred, where it was practicable, to give the opinions of the various gentlemen in their own language. Although I have expressed my surprise that steel has not been more largely employed in great engineering works and shipbuilding, I am well aware that there is much to be said in defence of the cautious policy which has guided our engineers and shipbuilders; and I have no desire to cast the slightest reflection on members of either profession for the exercise of a caution which, in all the circumstances, was perhaps natural. If blame there be, manufacturers must take to themselves a fair share of it, as at first, steel was made of unsuitable quality; and when this difficulty was got over, they were somewhat slow to put themselves in a position to supply the trade with steel of suitable sections at a moderate cost. For a long period, as I have said, steel was expensive, and this stood in the way of its general introduction. Makers have ascertained that it possessed great tensile strength as compared with wrought iron, were anxious that it should be used if possible with a comparatively high percentage of carbon, so as to retain this excellent quality; and at first steel with a tensile strength of forty tons per square inch and upwards was made into plates and used for other purposes, for which, as experience has since proved, it was unfitted. There is now, however, amongst the manufucturers a perfect knowledge of what is wanted for various engineering purposes. There is also the power to produce steel of almost any shape or quality at a moderate cost, and it only requires the hearty co-operation of the engineering profession to induce manufacturers everywhere to erect suitable machinery for converting steel into the necessary forms for constructive purposes; and if reasonable encouragement is given in this direction, I have no doubt that healthy competition will soon bring the cost of steel to a point where it will, as a matter of economy, beat certain classes of iron out of the field. I assume, of course, that upon proper proof being given of the superiority of steel, the Board of Trade will modify their rules as to its use. Although the proper business of this Institute is to discuss technical subjects, I will venture to follow the example of my predecessor, and say something of the present position and prospects of our trade. At our last annual meeting, Mr. Bell concluded his excellent address with the following hopeful and spirited remarks: "Whatever difficulty may be-

set us at the present moment, it can only be of a temporary character. Of raw materials we have an abundance; of our skill as manufacturers, whatever may be said to the contrary, we have no reason to be ashamed, and it will be a strange thing if, with these advantages, British energy is unable to hold its own against any people in the world." If England had a fair field she would, beyond doubt, hold her own; and further would continue to be for a long period, as far as iron is concerned, the workshop of the world. But from many important markets in Europe, and from the United States of America, English iron and steel are practically excluded. Heavy import duties are imposed with the avowed purpose of encouraging native manufacture, which means excluding the manufactures of England. The effect of this policy is being severely felt at the present moment, for we have but little demand from Europe, and we seem to have lost our American market entirely.

With our free trade notions we all believe that our neighbors in Europe and our friends in the United States are pursuing a mistaken policy, that they had better confine themselves to the charming Arcadian occupations of growing fine "corn and wine," and let England continue to drudge in the grimy business of iron and steel making. Some sanguine persons believe that some day they will see the error of their ways, and that they will adopt the course above indicated. I confess that on this point I am far from hopeful. If it were merely a trade question we might expect that by and by the example of England would be followed as a matter of self interest, but it is needless to say that in powerful countries the home production of iron and steel means more than giving employment to a portion of the population. In certain contingencies it renders a nation independent of foreign supplies at times when such dependence would cripple the most powerful nation in the world. There is, moreover, another reason why we can hardly expect to see, within a reasonable time, the principles of free trade introduced. Governments have encouraged the growth of gigantic industries devoted to the manufacture of iron and steel; and any one who has had the privilege of seeing the vast works of Creusot and Essen, would, I think, admit that no Government, however wise or strong, would lightly venture on a policy which would interfere with the prosperity of such establishments. We must, I think, frankly accept the position in which we are placed, and prepare to seek new markets for our produce in countries which, even if they have the will, have not yet the power to impose restrictions on our trade.

STRAINS IN CONTINUOUS GIRDERS.

By MANSFIELD MERRIMAN, C. E., New Haven, Conn.

Written for Van Nostrand's Magazine.

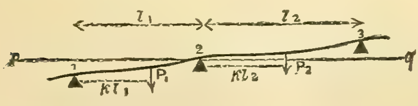
In designing a bridge truss continuous over many supports the engineer is often at a loss for want of English treatises on that subject. Such as he is able to consult, he is generally apt to find unsatisfactory on account of their incompleteness, or the tediousness of the approximate methods used. Although the later works of German and French writers contain the complete and satisfactory theory of the continuous girder under every variety of loading, the results have not yet been made available to the practical engineer. In fact the formulae for the maximum bending moments in every section due to a combination of the dead and live loads are complex, and not easy of application. Such formula are, however, entirely unnecessary for the calculation of strains in any truss. They do not shorten the work, but rather impede it, particularly in the hands of those to whom algebraic expressions are not thoroughly familiar.

The maximum stresses in a continuous truss may be easily and completely determined, *when the moments and vertical forces at every support due to any position of a concentrated load can be found.* In a simple girder, we know at once from

the law of the lever, the reactions at the abutments; but in a continuous girder they are not so easily obtained. In fact it is not generally known among American engineers that the shearing forces, due to a single concentrated weight on a girder continuous over any number of supports, can be computed. Although the extension of Clapeyron's theorem to concentrated loads was published ten years ago, and has since been prominent in German and French engineering works, it has not yet gained the attention of the English and American public. For example, in a recent work on the Analysis of Bridge Trusses, by the graphical method it is stated that "a complete solution for the bending moment and shearing force at every section, under moving partial and irregular loads, is well nigh impossible, on account of the complexity of the formula, so far as any practical application of them by the engineer is concerned," and the same author* frequently asserts that Clapeyron's theorem can only be used for uniformly distributed loads.

I propose to give in this article a demonstration of the Theorem of Three Moments for the case of girders of constant cross section, subject to loads either regular or irregular, uniform or concentrated, and to show how the reactions due to such loads can be found. Then by practical examples I shall show how the maximum moments and shearing forces at every section can be computed, without the aid of any formulae, except those for finding the moments and vertical forces at the supports, by a method as simple and as easily applied by the engineer as those in common use for the case of a truss of one span.

Let l_1 and l_2 be two spans of a girder continuous over any number of supports, the supports being either on the same or different levels, and the two ends either fastened or lying free upon abutments.



The moment at a support will be designated by the letter M with an index corresponding to that of the support, thus M_2 and M_3 are the moments at the supports 2 and 3. The reaction will be represented by R in the same way. In the span l_1 let there be a single concentrated load, P_1 at a distance kl_1 from the left hand support, also in the span l_2, a load P_2 at a distance kl_2 from 2; k being any fraction and not necessarily the same in the two cases. Let us take the support 2 as an origin; and designate by **m** the moment at any point in the span l_2. Now if we consider any section between the load P_2 and the support 3, we know the sum of the moments of all the exterior forces acting upon the beam upon the left of this point must be equal and opposed to the moment of the molecular forces in the section. Now all the exterior forces to the left of the point 2 may be conceived as acting at 2 in the unknown moment M_2 and an unknown vertical shearing force S_2. Denoting the distance of the section from the origin by x; we have the equation of moments with reference to this section:

$$(1) \quad M_2 - S_2 x + P_2 (x - kl_2) - \mathbf{m} = o$$

Making in this $x = l_2$, **m** becomes M_3, and we have

$$(2) \quad S_2 = \frac{M_2 - M_3}{l_2} + P_2 (1 - k)$$

Considering now a section in the span l_1 between P_1 and the support 1, we have all the exterior forces to the right of 2 represented by the moment M_2 and an unknown vertical force S'_2, and the equation of moments for that section is analogous to (1); making $x = l_1$, we deduce the value

$$(3) \quad S'_2 = \frac{M_2 - M_1}{l_1} + P_1 k$$

Now the reaction at the point 2 is the sum of these two partial reactions, hence adding (2) and (3) we have

$$(4) R_2 = \frac{M_2 - M_1}{l_1} + \frac{M_2 - M_3}{l_2} + P_1 k + P_2 (1 - k)$$

Hence the shearing force and the reaction at any support may be obtained when the moments at that support and at the preceding and following supports are known.

These are found by the wonderful

* C. E. Greene, *Graphical Method for the Analysis of Bridge Trusses.* D. Van Nostrand, New York. 1875.

Theorem of Three Moments, of which an abridged demonstration will now be given. Through the origin pass a horizontal line $p\,q$, and let the height of any support *above* that line be denoted by h. Let the tangent of the angle which the elastic curve at any point makes with this horizontal be denoted by t. The well known equation of the elastic line is

$$(5)\quad \frac{d^2 y}{d x^2}=\frac{\mathbf{m}}{E\,I}$$

Where E is the modulus of elasticity, I the moment of inertia of the girder, and **m** the moment at the point whose coordinates are x and y. Inserting for **m** its value from (1) we have

$$(6)\quad \frac{d^2 y}{d x^2}=\frac{M_2-S_2\,x+P_2\,(x-k\,l_2)}{E\,I}$$

Integrating this once, the constant of integration is t_2 the tangent at 2, and

$$(7)\quad \frac{d\,y}{d\,x}=t_2+\frac{2\,M_2\,x-S_2\,x^2+P_2\,(x-kl_2)^2}{2\,E\,I}$$

Integrating again the constant is zero, and

$$(8)\quad y=t_2\,x+\frac{3\,M_2\,x^2-S_2\,x^3+P_2\,(x-k\,l_2)^3}{6\,E\,I}$$

Making in (8) $x=l_2$ we have $y=h_3$, and substituting for S_2 its value from (2) we have for t_2 the expression

$$(9)\quad t_2=\frac{h_3}{l_2}-\frac{1}{6\,E\,I}\left(2M_2\,l_2+M_3 l_2-P_2\,l_2^2\,[2\,k-3\,k^2+k^3]\right)$$

If now we make in (7) $x=l_2$, $\frac{d\,y}{d\,x}$ becomes t_3, and by substituting in (7) the value of t_2 from (9), we get

$$(10)\quad t_3=\frac{h_3}{l_2}+\frac{1}{6\,E\,I}\left(M_2\,l_2+2\,M_3\,l_2-P_2\,l_2^2\,[k-k^3]\right)$$

Considering now the origin at the support 1, we may derive a value for t_2 by simply diminishing each of the indices in (10) by unity, therefore

$$(11)\quad t_2=\frac{h_2}{l_1}+\frac{1}{6\,E\,I}\left(M_1 l_1+2\,M_2\,l_1-P_1 l_1^2\,[k-k_3]\right)$$

Comparing (9) and (11) the tangents will eliminate, and we have

$$(12)\quad M_1\,l_1+2\,M_2\,(l_1+l_2)+M_3\,l_2=6\,E\,I\left(\frac{h_1}{l_1}+\frac{h_3}{l_2}\right)+P_1 l_1^2\,(k-k^3)+P_2\,l_2^2\,(2\,k-3\,k^2+k^3)$$

Which is the most general form of the theorem of three moments for a girder of constant cross section. When the origin is at 1 as in (11) the line $p\,q$ is supposed to pass through that support, and since (12) refers to the support 2, h_2 should be replaced by $-h_1$, as is there done. If the supports are all upon the same level $h=o$, and the second member of the equation contains only loads involving P. If there be several loads, it is only necessary to prefix the sign of summation Σ to the two terms involving P. For the case of a uniform load w_1 and w_2 per unit of length, we have only to put $\Sigma\,P_1=w_1\,d\,(k\,l_1)$ and $\Sigma\,P_2=w_2\,d\,(k\,l_2)$, and to integrate between the required limits; thus, if the load cover both spans entirely, the integral is taken between the limits o and l, and we have (if the supports are on the same level)

$$(12)^*\quad M_1\,l_1+2\,M_2\,(l_1+l_2)+M_3\,l_2=\tfrac{1}{4}\,w_1\,l_1^3+\tfrac{1}{4}\,w_2\,l_2^3$$

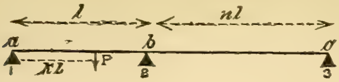
And the reaction for the corresponding support becomes, from (4)

$$(13)\quad R_2=\frac{M_2-M_1}{l_1}+\frac{M_2-M_3}{l_2}+\tfrac{1}{2}\,w_1\,l_1+\tfrac{1}{2}\,w_2\,l_2$$

When the supports are on the same level, and the ends of the girders lie upon abutments, formula (4) and (12) are of easy application. The moments at the ends are then zero, and for each intermediate support may be written an equation of the form of (12) by which the moments can be found, since the number of equations is the same as that of the unknown qualities. Then by substitution in expressions of the form of (4) the reactions become known.

If we have two spans $a\,b=l$, $b\,c=n\,l$, there is only one equation of moments. Let us apply this to a single concentrated weight on the span $a\,b$. Referring to (12), we have then

* This is the form as first deduced by Clapeyron, *Comptes Rendus*, 1857. The form as given in (12) is due to Bresse, *La Mécanique Appliquée*, 1865. A more general extension to the case of variable moment of inertia is given by Weyrauch, *Theorie der Continuirlichen Träger*, 1873.



(14) $2\,M_2\,(l+n\,l)=P\,l^2\,(k-k^3)$ or

$$M_2=\frac{P\,l}{2+2\,n}(k-k^3)$$

Then from (4) we have

$$R_1=-\frac{M_2}{l}+P\,(1-k)=$$

$$\frac{P}{2+2\,n}\left(2+2\,n+\;(3+2\,n)\,k+k^3\right)$$

(15) $$R_2=\frac{M_2}{l}+\frac{M_2}{n\,l}+P\,k=$$

$$\frac{P}{2\,n}\left([2\,n+1]\;k-k^3\right)$$

$$R_3=-\frac{M_2}{n\,l}\qquad=$$

$$-\frac{P}{2\,n+2\,n^2}\left(k-k^3\right)$$

Now for our practical illustration, let $a\,b=80$ ft. and $b\,c=100$ ft, hence we have $n=1.25$, and the formula become

$$R_1=\;\;P\,(1-1.222\,k+0.222\,k^3)$$

(16) $$R_2=\;\;P\,(1.4\,k-0.4\,k^3)$$

$$R_3=-P\,(0.177\,k-0.177\,k^3)$$

For a load P′ on the span $b\,c$, we may call $b\,c=l$ and $a\,b=n\,l$, and estimate the abscissa of the load by $k\,l$ measured from the support c. Then we have $n=0.8$, and from (15) we have

(17) $R_1=-P'\,(0.3742\,k-0.3742\,k^3)$ etc.

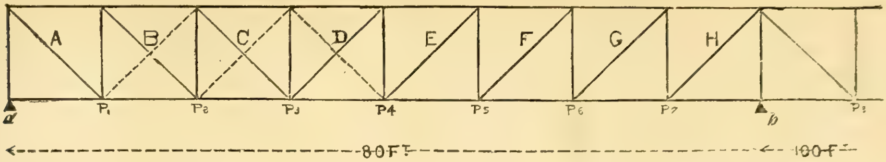
Suppose now the span $a\,b$ to be divided into eight and $b\,c$ into ten panels. Let the dead load of the truss be 2.5 tons per panel, and the live load 5 tons. To find all the strains in the span $b\,c$ it is only necessary to compute the reactions at a due to a load $P=P'=5$ tons for every panel point. Putting then, in the first of formula (16), k equal successively to $\frac{1}{8}$, $\frac{2}{8}$, $\frac{3}{8}$, etc., we find the values for all loads on the span $a\,b$; then in (17) making $k=\frac{1}{10}$, $\frac{2}{10}$, etc., we get the values for loads on $b\,c$. There are given in the annexed table, P_1 to P_7 inclusive, being the loads on the span $a\,b$, as shown in the diagram given below, while P_8 to P_{16} are

REACTIONS AT a, P=4 tons.

Load.	R_1	Load.	R_1
P_1	+4.24	P_8	—0.29
P_2	+3.49	P_9	—0.54
P_3	+2.77	P_{10}	—0.65
P_4	+2.08	P_{11}	—0.66
P_5	+1.45	P_{12}	—0.65
P_6	+0 88	P_{13}	—0.58
P_7	+0.39	P_{14}	—0.47
		P_{15}	—0.33
		P_{16}	—0.17
P_1—P_7	+15.30	P_8—P_{16}	—4.34

the loads on the span $b\,c$, P_8 being the one nearest to the pier b, and the others following in the order of their indices. The computation of reactions is always very simple when the formula are once put into the shape of (16) and (17), and may be done by an office-boy acquainted with only the first elements of algebra. However great the number of spans, there will never be more than three terms involving k, the numerical coefficients of which may be deduced for every case by a process similar to that illustrated above.

Let us take the Murphy-Whipple pattern as the style of our practical example; the vertical posts are to be struts, and the diagonals ties. The load is to be applied to the lower chord. We then know that the ties near the end a, must slope upward toward the abutment, and that those near b must slope upward toward the pier. These two systems of ties must meet at the panel point where the shearing force due to a uniform load changes from positive to negative. In a simple girder this point is at the middle of the truss. From our table of reactions, we see that a reaction at a for a uniform load of 5 tons per panel is $15.30-4.34=10.96$ tons, and this is the positive shearing force in the panel A, for the panel B we have $10.96-5=5.96$ tons, for C $5.96-5=0.96$, and for D $0.96-5=-4.04$ tons. Hence the two systems of ties meet at the panel point between C and D. From the table of reactions we may now tabulate the shearing forces due to each weight. Taking for instance the load P_2, its reaction is $+3.49$ tons; this acts as a positive shear in the panels A and B; for all the other



Shearing Forces.

		A	B	C	D	E	F	G	H
1	P_1	+4.24	—0.76	—0.76	—0.76	—0.76	—0.76	—0.76	—0.76
	P_2	+3 49	+3.49	—1.51	—1.51	—1.51	—1.51	—1.51	—1.51
	P_3	+2.77	+2.77	+2.77	—2.23	—2.23	—2.23	—2.23	—2.23
	P_4	+2.08	+2.08	+2.08	+2.08	—2.92	—2.92	—2.92	—2.92
	P_5	+1.45	+1.45	+1.45	+1.45	+1.45	—3.55	—3.55	—3.55
	P_6	+0.88	+0.88	+0.88	+0.88	+0.88	+0.88	—4.12	—4.12
	P_7	+0.39	+0.39	+0.39	+0.39	+0.39	+0.39	+0.39	—4.61
	P_8—P_{16}	+4.34	—4.34	—4.34	—4.34	—4.34	—4.34	—4.34	—4.34
2	Live Load +	+15.30	+11.06	+7.57	+4.80	+2.72	+1.27	+0.39	
3	Live Load —	—4.34	—5 10	—6.61	—8.84	—11.76	—15.31	—19.43	—24.04
4	Sums	+10.96	+5.96	+0.96	—4.04	—9.04	—14.04	—19.04	—24.04
5	Dead Load	+5.48	+2.98	+0.48	—2.02	—4 52	—7.02	—9.52	—12.02
6	+ Maxima	+20.78	+14.04	+8.05	+2.78				
7	— Maxima		—2.12	—6.13	—10.86	—16.28	—22.33	—28.95	—36.06

panels we have $+3.49-5.=-1.51$ tons. In this way all the shearing forces are readily tabulated, and the position of the load required to produce the maxima is seen by inspection. For the panel D we see that P_4 to P_7 inclusive give positive shears while all the other loads produce negative. The maximum positive shear will then obtain when the rolling load extends from D to the pier *b*, and the greatest negative shear when the span *b c* and the segment *a D* is covered. Adding then the positive values in the vertical columns we get the horizontal column 2, which gives the maximum positive shearing forces due to the rolling load of 5 tons per panel. Adding the negative values we get in 3, the negative maxima. Taking the sums of the quantities in 2 and 3, we have in 4 the shearing forces due to a dead load of 5 tons per panel. Since the dead load is 2.5 tons per panel, we take one-half of these quantities, which gives us in 5 the shears due to the actual dead load. Then the positive maxima are the sums of the values due to the dead load and the maximum values for the live, that is the sums of the numbers in 2 and 5 give the positive maximum shears which are placed in column 6. Similarly the negative maxima in 7 are obtained by the addition of the values in 3 and 5. For the panels B, C and D, we notice that either a plus or minus shear may occur, which necessitates the introduction of counter ties in those panels, and which are shown on the diagram by dotted lines. The shearing forces are the strains upon the posts, and multiplied by the secant of the angle which the diagonals make with a vertical, they give the strains upon the ties.

We may now pass to the calculation of the moments. Let those be taken as positive which tend to produce tension in the upper chord, while those causing compression will be negative. Suppose only one load upon the truss, say P_2, and consider its action upon the upper chord in the panel G. If the chord be cut at this panel, revolution will begin at the

intersection of the diagonal and lower chord, the point marked by P_6 in the figure. This then is the centre of moments. The reaction of P_2 is 3.49, and its lever arm with reference to the centre of moments is the length of six panels or 60 feet. The moment of the reaction is then -3.49×60, the negative sign being used because it tends to turn the system in a right-handed direction about the centre of moments, and hence to cause compression in the upper chord. The lever arm of P_2, with reference to the same point, is the length of four panels or 40 feet, hence its moment is 5×40, with a positive sign since it acts downward. Then the total moment for the upper chord in the panel G is

$$5 \times 40 - 3.49 \times 60 = -9.4 \text{ ft. tons.}$$

In this way the moments due to every concentrated load are readily obtained and tabulated. Since all of the loads in the span *b c* produce a negative reaction at *a*, the moments due to their action is simply obtained by the product of the reaction -4.34 into the various lever arms, 10, 20, etc.

An inspection of this table shows that the maximum negative moment for all the upper chords, except that of the panel H, is produced when the span *a b* is fully loaded and *b c* unloaded. For H the negative maximum occurs when only the loads P_5, P_6 and P_7 are present, and the positive maximum when these three are absent and the remainder of the girder loaded. Adding the positive and negative values we get in the horizontal columns 2 and 3, the maxima due to the live load. Taking one-half of the algebraic sum of the numbers in 2 and 3, we get in 4 the moments due to the dead load of 2.5 tons per panel. Then

MOMENTS FOR UPPER CHORD.

			A	B	C	D	E	F	G	H
1		P_1	—42.4	—34.8	—27.2	—27.2	—19.6	—12.0	—4.4	+3.2
		P_2	—34.9	—69.8	—54.7	—54.7	—39.5	—24.5	—9.4	+5.7
		P_3	—27.7	—55.4	—83.1	—83.1	—60.8	—38.5	—16.2	+6.1
		P_4	—20.8	—41.6	—62.4	—62.4	—83.2	—54.0	—24.8	+4.4
		P_5	—14.5	—29.0	—43.5	—43.5	—58.0	—72.5	—37.0	—1.5
		P_6	—8.8	—17.6	—26.4	—26.4	—35.2	—44.0	—52.8	—11.6
		P_7	—3.9	—7.8	—11.7	—11.7	—15.6	—19.5	—23.4	—27.3
		$P_8—P_{16}$	+43.4	+86.8	+130.2	+130.2	+173.6	+217.0	+260.4	+303.8
2	Live	—	—153.0	—256.0	—309.0	—309.0	—312.0	—265 0	—168.0	—40.4
3	Load	+	+43 4	+86.8	+130.2	+130.2	+173.6	+217.0	+260.4	+323.2
4		Sums	—109.6	—169.2	—178.8	—178.8	—138.4	—48.0	+92.4	+282.8
5		Dead Load	—54.8	—84.6	—89.4	—89.4	—69.2	—24.0	+46.2	+141.4
6		— Maxima	—207.8	—340.6	—398.4	—398 4	—381.2	—289.0	—121.8	
7		+ Maxima		+2.2	+40.8	+40.8	+104.4	+193.0	+306.6	+464.6

combining 5 with 2 and 3 we get in 6 and 7, the negative and positive maximum moments due to the combination of the dead and live loads.

For the lower chord the centres of moments will be at the intersection of the ties with the upper flange. Hence we have the moment for A equal to zero, and the moments for B, C, D, E, F, etc., will be the same with a reversed sign as those for the upper chord in A, B, E, F, G, etc. Only the moment for the lower chord in H remains to be found. This may be computed in the same way as those above. Its value is 523.2 ft. tons.

Let the height of the truss be 10 feet. Then from the table of shears the maximum stresses for the diagonals are found by multiplying by the secant of 45° or $\sqrt{2}$.

From the table of moments the chord strains result by dividing by the depth of the truss. Hence the following table of

MAXIMUM STRAINS.

	A	B	C	D	E	F	G	H
Left Hand Post......	—20.8	—14.0	—8.1	—8.9	—10.9	—16.3	—22.3	—29.0
Tie.................	+29.7	+19.6	+11.3	+15.3	+22.8	+31.3	+40.6	+50.5
Counter tie...........		+3.0	+8.6	+3.9				
Upper chord...	—20.8	—34.1 +0.2	—39.8 +4.1	—39.8 +4.1	—38.1 +10.4	—28.9 +19.3	—12.2 +30.7	+46.5
Lower chord.........	0.0	+20.8	+34.1 —0.2	+38.1 —10.4	+28.9 —19.3	+12.2 —30.7	—46.5	—52.3

Where + denotes tension and — compression. To complete the calculation for the span bc it is only necessary to find the strain in the post over b. This is evidently a maximum when the whole girder is covered with both dead and live loads, and is equal to the reaction of the pier, or to the sum of the shearing forces in the two adjacent panels. From (16) and (17) we find the reaction at b for that case to be 77.5 tons, which is the value of the maximum compression in the post.

To recapitulate then the processes for finding the maximum strains in the end spans of any continuous truss; compute the reactions at the free end by the formula (4) and (12) for a single load at each panel point. Then tabulate the shearing forces in every panel due to each weight and deduce the maximum shears by a combination of the dead and live load, as fully explained above. Then from the reactions compute the moments due to single loads. From the shears the strains in web are found, while the moments give the stresses for the chords.

The truss which has been computed above is the simplest form of a continuous girder. There being no moment at the abutments the computations of the ends reactions is alone sufficient to determine the strains; but as we see from (1) the moment at any section depends upon the moment at the support, and when these exist they must be taken into account. If it be required to compute a truss of six spans, we need then to find the moment and shear at each support for every position of a single weight. These can be determined by the Theorem of Three Moments for every case, but when the number of spans becomes great the preliminary calculation of these quantities is tedious. A general solution of the equations of moments can, however, be made, and put into shape for direct use.

I propose now to present without demonstration a few simple expressions that contain the whole theory of continuous girders over level supports. A proof for analogous expressions as applied to girders of equal span may be seen by the reader in the "Journal of the Franklin Institute," for April, 1875. These formula will give the moments at every section due to a single load P, and the shearing force at the right hand side of every support. They will be found by the engineer to be easy of application, and in connection with the method of tabulation given above will completely solve every girder.

Let V s= number of spans, l_r = length of the span containing the load P, l_1 l_2 l_3, etc., the length of the spans counting from the left hand end, and l_s, l_{s-1}, etc., beginning at the right hand end. In the same way let the supports be numbered 1, 2, 3, etc., then r will denote the support at the left of the loaded span. A single load will be called P, and its distance from the r^{th} support will be a, or $k\, l_r$ where k denotes any fraction.

The moment at any support will be called M_n, and the shearing force at a point infinitely near to the support will be designated by S_n.

Then the moments and shears due to a single load P will be given by the following formulae :

(I.) The moments at the supports

when $n<r+1$,

$$M_n = c_n \frac{A\, d_{s-r+2} + B\, d_{s-r+1}}{l_2\, d_{s-1} + 2\,(l_1+l_2)\, d_s},$$

and when $n>r$,

$$M_n = d_{s-n+2} \frac{A\, c_r + B\, c_{r+1}}{l_{s-1} c_{s-1} + 2\,(l_{s-1}+l_s)\, c_s}$$

(II.) The shears at the supports

at the r^{th} $\quad S_r = \dfrac{M_r - M_{r+1}}{l_r} + P\,(1-k)$

at any other $\quad S_n = \dfrac{M_n - M_{n+1}}{l_n}$.

(III.) The moments at any section, whose distance from the left hand support is x.

Between P and the right hand support
$$\mathbf{m} = M_r - S_r\, x + P\,(x-a)$$

At any other section $\quad \mathbf{m} = M_n - S_n\, x$

The constants $c_1\, c_2\, c_n$, etc., and $d_1\, d_2\, d_s$, etc., depend only on the lengths of the various spans; A and B depend only on the load P and its position in the r^{th} span; the values of these constants are :

$$c_1 = 0$$
$$c_2 = 1$$
$$c_3 = -2\,\frac{l_1+l_2}{l_2}$$
$$c_4 = \frac{4\,(l_1+l_2)\,(l_2+l_3) - l^2_2}{l_2\, l_3}$$
$$c_5 = -2\, c_4 \frac{l_3+l_4}{l_4} - c_3 \frac{l_3}{l_4}$$

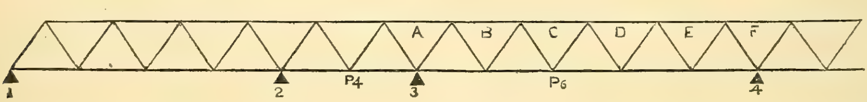
etc. etc.

$$d_1 = 0$$
$$d_2 = 1$$
$$d_3 = -2\,\frac{l_s+l_{s-1}}{l_{s-1}}$$
$$d_4 = \frac{4\,(l_s+l_{s-1})\,(l_{s-1}+l_{s-2}) - l^2_{s-1}}{l_{s-1}\, l_{s-2}}$$
$$d_5 = -2\, d_4 \frac{l_{s-2}+l_{s-3}}{l_{s-3}} - d_3 \frac{l_{s-2}}{l_{s-3}}$$

etc. etc.

$$A = P\, l_r^2\, (2k - 3k^2 + k^3) \qquad B = P\, l_r^2\, (k - k^3)$$
$$k = \frac{a}{l_r}$$

To apply these to any case we first insert the lengths of the spans in the series c and d. For six spans we need only to use them as far as c_6 and d_6. Then take a load on the first span, or $r=1$, and making n equal to 2, 3, 4, etc., find from (I.) the moments at every support. For example, let us take a girder of six spans, one-half of which is represented in the sketch, and the other half of which is symmetrical to this



or $l_1 = l_6 = 80'$ $l_2 = l_5 = 40'$ $l_3 = l_4 = 100'$.

Inserting these values in the series c and d we get

$$\begin{aligned} c_1 &= d_1 = 0 \\ c_2 &= d_2 = 1 \\ c_3 &= d_3 = -6 \\ c_4 &= d_4 = 16.4 \\ c_5 &= d_5 = -59.6 \\ c_6 &= d_6 = 222. \end{aligned}$$

Now to compute the span 3—.4, we need to find the moments at 3 and 4 for a load at every panel point. This is easily done from formula (I). For example, take the load P_4 in the second span, here $r=2$, and $n=2$, hence we get

$M_3 = 1.873\ P_4\,(4k + 3k^2 - 7k^3)$, or since $k=\frac{1}{2}$, $M_3 = 3.513\ P_4$

and $M_4 = -0.525\ P_4\,(4k + 3k^2 - 7k^3)$ or $M_4 = -0.985\ P_4$

Then the shearing force due to P_4 is by (II)

$$S_3 = \frac{M_3 - M_4}{l_3} = 0.045\ P$$

From the moment M_3 and the shearing force S_3 the moment for any section can be found. Then by a tabulation of the moment due to every load the maxima are easily obtained as shown above.

If the dead load be 10 tons per panel and the live 20 tons; the height of the truss 10 feet, the maximum strains in the upper chord are:

A	B	C	D	E	F
+184. tons.	+52.4	+16.9 —26.4	+31.1 —29.0	+96.3	+220.6

By comparing these with the strains in a simple girder of the same span, height and load, the reader will observe that the continuous girder effects a saving of over twenty per cent. in material.

BUILDING MATERIALS AS REPRESENTED AT VIENNA.

From "The Builder."

Few things are likely to prove more instructive to the architect, or to the builder, than a comparative view of the character of building materials, as now employed, not only in this country, but on the Continent. For such a glance the reports and technical papers relating to the Vienna Exhibition furnish valuable information. The collections of building materials there exhibited were of sufficient importance to prove of great interest to the engineer, the architect, and the builder, although it was difficult to obtain a clear and satisfactory view of the whole of them; as they were divided into two groups, and scattered through the various galleries, the pavilions, and the grounds.

The United States sent specimens of a fine red sandstone, known as Connecticut freestone. This stone is much employed in New York; as its appearance is much in its favor, and it is easily worked. The price is about half that of granite. A yellow sandstone, easy to cut and to carve, was exhibited from Cleveland, Ohio; and specimens of granite from Vermont; and of red, white, black, and red-grained marble; completed the list of the American exhibits of this class.

From England, the specimens forwarded were principally those of artificial, rather than of natural, building materials. Of the latter, the samples of slate were most worthy of notice, and far excelled any from other countries. A slab from the Welsh Slate Company was 9 feet 10 inches long, and 6 feet 3 inches wide, weighing 32 cwt. At the other extremity of the scale of size, plates of only four hundredths of an inch in thickness, were also shown. Fine building materials, including sandstones, limestones and clay, were contributed from Canterbury, in New Zealand; and Queensland sent specimens of marble and of clay.

Amongst artificial building materials, the first place seems to have been accorded to the Portland cement, which is manufactured on the banks of the Thames and of the Medway. The materials employed are chalk and clay, and the works are, for the most part, situated on the chalk, the clay being brought to the manufactory from a distance. In the cement works on the banks of the Thames, the white, or upper chalk, in a portion of which flint bands and modules occur, is used. On the Medway, the gray, or lower chalk, in which much siliceous matter is distributed through the mass, so that it serves for a very fine material for interior work, is employed. The clay is the common dark blue clay, which is obtained in any requisite quantity along the shores of the confluent rivers. It consists of 68 per cent. of silica, 12 per cent. of alumina, 15 per cent. oxide of iron, with a small quan-

tity of alkaline matter, and a trace of lime.

Cement is manufactured either by a wet or a dry process. In the former, some four parts of gray chalk, or three of white, mixed with one of clay, are ground with water in a mill, until they attain the consistency of cream. This is allowed to flow from the mill into settling-tanks; whence it is removed, when dry, to hot plates. It is then burnt in a kiln, and finally reduced to powder in a grinding-mill.

The dry process is much used on the the Continent. The chalk and clay are first dried, then broken up, and then ground between vertical stones. The powder is placed in a pug-mill, and mixed with water containing freshly-burned chalk, with the addition of a little calcined soda, in the proportion of three measures of powder to one of water. The semi-fluid thus produced is cut into bricks as it issues from the pug-mill, in a continuous stream 10 inches wide and 5 inches deep. These blocks are removed on boards, dried, baked in a kiln, and finally ground to powder. It will be seen that although the latter is called a dry, and the former a wet, process, the chief difference lies in the amount of water which, in one or the other series of operations, is first mixed with calcareous, agrillaceous, and siliceous matter, and afterwards driven off by heat.

The selenitic mortar invented by Lieutenant-General Scott, R.E., is another artificial building material, described in the same reports. The process of production consists in mixing, with the water used in the preparation of the mortar, a small quantity of sulphate of lime, in the form of either plaster of Paris,* gypsum, or green vitriol. The water and sulphate are first mixed in a pan, the lime is then added, and the mixture is worked into a creamy paste. After grinding for three or four minutes, the sand, burnt clay, or other ingredient used in the composition is added, and the whole is ground for ten minutes more. It is claimed that by this invention ordinary lime can be at once converted into an excellent cement-like mortar, which sets rapidly and well, and can be used for masonry, concrete, or plasterers' work.

General Scott applies a modification of the same process to the manufacture of bricks. He mixes one part with lime, eight or ten parts sand or burnt clay, and produces bricks which are said to be ready for use in about ten days after pressing, without being burned. The addition of sulphur to the lime used is also said to have the effect of preventing the swelling of the brick, from the water absorbed by the lime in process of stacking.

An invention of posterior date to that of the selenitic mortar, is General Scott's sewage cement. The principle of this manufacture is the precipitation of the solid ingredients of sewage, and the removal of their organic constituents by burning. In the mineral deposit which is left, substances are present which are analogous to the components of the limestones that are used in the manufacture of hydraulic cement. The residue after calcination bears the nearest affinity to Portland cement, which is produced by calcining three parts of chalk with one of clay. But the state of comminution in which the material existed in the sewage is such as to make the mixture more homogeneous than in the case of the Portland process. It should be remarked that the calcined residuum is said to be valuable as manure, not only from the lime which it contains, which would be of service on arenaceous or agrillaceous soils, but also from the presence of from 1 to 2 per cent. of phosphoric acid. It is on this element that the utility of sewege as manure principally depends. The organic matter contained in sewage is not a material which the roots of plants can assimilate. It is the chief source of danger in case of neglect.

In pottery, the exhibits do not appear to have come up to the number or quality of those which we have hitherto described as displayed at South Kensington. The encaustic tiles of Messrs. Minton, made from Kaolin and various colored clays, dried and pressed, the glaze being obtained from felspar, are well known. Mr. Robert Minton Taylor exhibited a novelty, under the name of mosaic tiles. They consist of small cubes of about $\frac{1}{8}$ inch on the side, closely compressed in a powerful press, and afterwards burnt. A third specialty consisted in the majoli-

ca tiles, made of white clay, with drawings either painted or printed, partly under and partly on the glazing. While small in number, these exhibits were exquisite in quality.

The natural building materials supplied from France contained a large collection of slates from the Ardennes. Roofing slates, in thickness of from $\frac{1}{8}$ inch to $\frac{3}{16}$ inch, ranged in color from a pale red to a clear pale blue. Other specimens exhibited enamelled paintings on a highly polished dark ground, of the natural color. A beautiful fine-grained white sandstone is supplied from the Drôn. French marbles are numerous and excellent. The fine Griotte d' Italie and Griotte Compan marbles are dark red, with spots of a dark color, and white veins. They come from the quarries of Félines-Hautpoul (Hérault). The Languedoc is another marble from the same quarries, with white spots, and dark in veins. A light red marble, with spots of a darker red, comes from the Hautes Pyrénées. The Breche Impériale is a light-colored marble, clouded with red and grey, spotted with red and yellow, and darkly veined. It is quarried near the mouth of the Rhone. The Grand Antique, from La Rochelle, has an almost uniform red hue. A dark green marble, veined here and there by both lighter and darker streaks, which takes a beautiful polish, comes from the Basses Alpes. A fine white statuary marble, not unfit to compete with those of Italy, is quarried in the Haute-Garonne, and known as the Blanc de Béat. The transparent onyx marbles, with which we have had the opportunity of making ourselves acquainted at South Kensington, are not found in France, but are imported from Mexico. A similar, but somewhat inferior quality, is found in Algiers.

The art tiles manufactured by M. Deck, and those of M. Collinet, both of Paris, are excellent in design and in execution, although their price is too high to allow of a very general introduction of this decorative material. The bright colors employed by M. Deck are heightened by a peculiar glaze ; most of the designs are Persian. M. Collinet has succeeded in the production of large tiles—some as much as a metre square. A special process, called *émail-cloisonné*, is applied to these large *panneaux*. A white glaze is first placed on the tile. On this the design is painted in black. During burning, the enamel contracts, which gives a relief to the drawing, the colors of which are heightened. A panel of 3 feet 3 inches square, thus finished, costs from £14 to £18.

In coarser pottery, and the manufacture of bricks, France was not a formidable competitor with ourselves. Some curved, wedge-shaped, and dove-tailed bricks, constructed for different special purposes, were sent from Mezieres.

The Boulogne cement is a remarkable manufacture, well known in France. Its ordinary color is yellow, but it is made into blocks of a pale blue tint. Plates of two metres long by one wide, and not more than $\frac{1}{4}$ inch in thickness, were exhibited with perfect surfaces. Thirty bricks, placed one on another in a pile, united by this cement, were suspended from a beam. The hydraulic lime of Lapage-du-Thiel is produced in large quantities in the Ardeches. As much as 18,000 cubic per diem is turned out from thirty-four furnaces, which use from 80 to 100 tons of coal. The slacking of the burnt limestone, which is carried on in sheds, is aided by jets of steam. Ten days are required to pulverize the mass, which is then passed through bolting-machines. The residuum is ground and made into cement. This lime is used to a large extent for harbor work, in the form of *béton*, or concrete ; blocks of which were exhibited that had been under water for twenty-five years, without showing any signs of change. The cement made from the refuse of the bolting-machines, mixed in equal proportions with sand, make good water-pipes, with smooth and even surfaces. A proportion of three-parts sharp new sand to one of the cement makes a serviceable brick. Colored tiles of various hues, paving, pedestals, and other architectural requisites, are made from the same material.

The "carton pierre" of MM. Hardouin and Lefevre, of Paris, is largely employed for architectural decoration in that city. Its superiority to plaster is so great that it would be interesting to know why the attempt made, some time since, to introduce this material into London has not been attended by more signal success.

The native marbles of Belgium may compete with those of France. Some very beautiful kinds are found in the province of Namur. The *Grive Gérard* is of a light grey color, with small black spots distributed regularly over the whole surface. The *Lilas* is of a brighter grey, with white and also very dark spots. The *Florence* is of a reddish grey color, with brown spots; the *Coquille* is bluish black, with light spots, in the form of mussel-shells; the *Marbre Bois* shows a fibrous pattern on a back ground. A pure black marble, from Mazy-Galzines, is remarkable for the facility with which it can be worked, a quality very rare in black marbles. It is worth as much as 15s. per cubic foot. Inferior marble suitable for pavements, can be obtained for a part of this price.

Roofing slates from Luxembourg are divided into fifteen different classes, varying in thickness, as in the case of the French slates, from $\frac{1}{8}$ in to $\frac{3}{16}$ in.

Fire-clays are wrought in the province of Namur, varying in color, from an almost perfect white, to dark bluish grey, and reddish brown. Fire-proof bricks, of a superior quality, are priced at from 32s. to 40s. per ton. Hearth blocks for welding furnaces fetch as much as 64s. per ton. Fire-bricks, from the province of Liege, are compressed by hydraulic pressure, and afford a dense, compact material at a reasonable price.

The bricks of Holland are described as sound and durable, though not, as a rule, well finished. The corners are rounded, and the surface coated with sand. They appear to be well burnt through, without vitrification on the outside, and are dense and very hard. The largest size is $8\frac{5}{8}$ inch by $4\frac{1}{8}$ inch by 2 inch ; and the price varies from 20s. to 40s. per 1,000. The second size is $6\frac{1}{4}$ inch by $6\frac{3}{8}$ inch, by $1\frac{9}{16}$ inch ; for which the price is from 8s. to 10s. per mille. Clinker bricks are supplied for paving. It is worthy of remark that the prices of machine-made bricks are 2 or 3 per cent. higher than of those which are made by hand.

Wall-tiles of white, pale blue, and lavender, of the well-known old Dutch patterns, vary in price between 60s. and 80s. per thousand. The usual size is 9 inch by 6 inch. Millions of these tiles are made annually at Utrecht, a little under 5 inch square, and costing from 8 to 10 centimes each, or about 64s. per thousand. They are also produced in finer qualities, at prices from 60s. to 68s. per thousand.

Denmark has shown but little of its building products, Messrs. Erichsen's roofing tiles being almost the sole exhibit. These are solid, flexible, and perfectly adapted to the requirements of the builder. Sweden only exhibited small specimens of her rich and varied stores of building-stones, granite, porphyry, marbles and limestones.

The varied and inexhaustible wealth of the Italian peninsula, in all that forms the material of the builder, the sculptor and the decorator, was well and completely represented at Vienna. The Italian Minister of Agriculture, Industry and Trade, exhibited a fine collection of stones for building, quarried and worked in Italy.

The physical conformation of the Spanish peninsula is such as to leave little room to doubt that the mineral products of that country are in no way inferior to those of Italy. Indeed, in the neighborhood of Logrono, there is said to occur excellent coal, while bituminous shale is the only combustible mineral with which we are acquainted as native in Italy. Many specimens of building-stone were sent from Spain, chief among which may be noted magnificent specimens of pure alabaster from Guadalajaro. Fine dark-colored slate is found in the same province. Marbles of various kinds are quarried in the Balearic Islands; and hydraulic limes and cements are also produced in Spain. Encaustic tiles, manufactured by Signor Nollo, of Valencia, are exported in large numbers to Italy and to South America. Messrs. Soto y Tello, of Seville, manufacture tiles colored with white, green, blue and black, made after designs taken from the works of the Alhambra, in the repairs of which building they are employed. Nothing, however, of merit approaching that of the famous Buen Retiro *faience* was forthcoming from Spain in 1873. In Portugal, mining industry has of late taken a fresh start, under the impulse given by a modification of the laws regulating mines and quarries. Marbles were exhibited from Estremas, and very fine

dark slates, some of which were almost black, are found in the district of Oporto.

The most numerous and most complete series of exhibits of building materials to be seen at Vienna came, as was naturally to be expected, either from the Dominions of the Austrian Emperor, or from those of his German brothers. Under the latter head, the Mining Commission of Alsace and Lorraine contributed a fine collection of some 180 specimens from the quarries of these provinces. These comprehend granite, gneiss, porphyry, various sandstones, limestones and marble. The dark yellow sandstone found in the vicinity of Halle was represented by a large lion, sculptured from the material. A grey sandstone from the same exhibitors was formed into a pedestal supporting a bust of the Crown Prince.

The granite from Silesia is remarkable for its excellence. A carefully-wrought slab, 16 feet long, 12 feet 4 inches wide, and 7 inches thick, was sent from Saarau, in this district. The slate quarries of Lehesten have been carried on since the tenth century. The color of the slate is dark blue, and its imperishable character is explained by the chemical analysis, which shows 64 per cent. of silicic acid, 17 per cent. of alumina, and 13 per cent. of various oxydes, combined with 4 per cent. of water, and but little more than 1 per cent. of carbon and carbonate of lime; the slate is fine in grain and regular in cleavage, producing plates as thin as .04 inch. The price also is low, and the consumption very large.

The Saxon serpentine, from the stone works of Zoblitz, appears to be free from the usual defect of this very beautiful material; a defect to which the serpentine of our own south-western district is liable, namely, the numerous cracks that divide the mass, rendering it impossible for the quarrymen to extract large and sound blocks. In the Norman, and also in the Florentine work, in which this material is used, the pieces are very small. The Zoblitz Company, however, produce not only large blocks, but veneers for covering surfaces of stone, and their work has attained a high degree of excellence. The usual color of this serpentine is a dark green; but black, red and yellow varieties also occur, and are used with good effect in mosaic.

The "cajalith" of M. Schmidt, of Dresden, is a beautiful artificial building material, the composition of which is kept secret by the inventor. It is nearly white, fine in grain, and closely resembles marble in appearance. When first made it is plastic, and may be moulded into any required form. It subsequently sets, and becomes extremely hard. It can also be made of any desired color, but the specimens of mosaic formed from cajalith, made in imitation of various natural stones, had suffered from exposure to the weather. As much as 50 tons of this material is now produced per month.

A tufa, found in the vicinity of the Laacher Sea, near Andernach, is interesting as showing the appearance, in this region, of this light, durable, volcanic material, which cuts with almost the facility of chalk; and to the abundance of which, in Italy, the introduction of the vault, as an architectural feature, may with great justice be attributed. The Andernach tufa, however, is blue; that of the South of Italy is of a pale yellowish brown. The analysis of the former shows it to contain 52 per cent. of silicic acid, 15 per cent. of alumina, and 11 per cent. of sesquioxyde of iron. It has been used since the time of the Normans, for the manufacture of hydraulic cement. As many as twenty-five cement-makers competed at Vienna from Germany. The tertiary clay, and the chalk, of Rügen and Stettin, and the deposits near the mouth of the larger rivers, as for instance near Emden, which are analogous to those of the Medway, are used for this manufacture. Light yellow bricks, inlaid tiles, glazed decorative plates, terra-cotta columns and capitals, a terra-cotta statue of Germania, mosaic tiles for pavements, fire-bricks and blocks for blast-furnaces, large clay retorts, up to the weight of 1½ ton, glazed tiles, and white Dutch tiles, gilded and brightly enamelled, are exhibits which say much for the industry of the clay-workers of Germany.

Artificial-roofing materials are also much in use in Austria. There were twenty-three exhibitors of felt, paper, wood and various cements, for this purpose. Herr Irmes, of Berlin, works up 1,500 tons of raw material into roofing material per annum. Zinc plates, color-

ed red, black and white, in imitation of tiles, were taken from a roof in Munich, where in twenty-seven years they had suffered but little loss of weight. Considering, however, the conducting power of metal, the instances can be but few in which a wise architect would substitute a thin zinc plate for a sound and impervious tile.

The building-stones of Austria are numerous and excellent. White, light grey, blue and yellow varieties of limestone are quarried in the Vienna basin. The Wöllersdorf stone is distinguished for great hardness and purity of color. The Mühlendorf limestone is of a similar quality, although in places it contains crystals of dolomite. A blue and yellow stone, from Sommerin, extremely hard in its lower bed, is known as Imperial stone. A fine white statuary limestone is found in the neighborhood of Neusiedeler. A fine sandstone, which has been used in the restoration of the Cathedral of St. Stephen, at Vienna, is from St. Margarethen. A fine red sandstone, variable as to quality, is quarried at Brun am Steinfeldt, and also at Baden. The Vienna or Karpathen sandstone is of a bluish-grey color, with a fine quartz base, cemented by lime and clay. It disintegrates by exposure to the atmosphere.

Marbles are found in Carinthia. Quarries of a dark red marble have recently been opened at Arnoldstein. A light-blue marble-like stone, with dark veins, which takes a high polish, and a fine-grained white and reddish limestone, with green veins, are largely used. Tufaceous limestone is also frequent in Carinthia. It is light, and easily quarried. Most of the slate used in Austria comes from the Silesian and Moravian provinces, which possess good qualities of green and of dark blue slates.

In the Lengau Valley about 30,000 tons of materials are annually worked up into hydraulic lime and cement. In Vienna, 50,000 tons of cement and hydraulic lime, and 12,500 tons of gypsum, are annually made and sold. Near Steinbrück, in Styria, an argillaceous marl slate and a dark blue limestone have been quarried for the same purpose for fourteen years. Building blocks, composed of broken stone and cement, are manufactured at Vienna.

The brick industry of Austria is also very active, a thousand million of bricks having been turned out from the various factories in 1870. The Wienenberger bricks, from their acknowledged excellence, are chiefly used for public buildings. The Wienenberger Company produce also tiles and objects in terra-cotta, and it is said to be owing to the magnitude of these works that the building for the Exhibition of 1873 was completed in time.

THE "BESSEMER."

From "Engineering."

The steamship "Bessemer" made her first public trip across the Channel, May 8th, carrying as passengers a large party who had accepted the invitations to a trip to Paris issued conjointly by the London, Chatham, and Dover Railway Company, the Bessemer Steamship Company, and the Northern Railway Company of France. A special train from the Victoria station conveyed the passengers to Dover, and shortly after eleven o'clock the "Bessemer" steamed out of Dover Harbor on her way for Calais. Of course, one of the chief attractions which had drawn the company together was the swinging saloon, and hence much disappointment was naturally expressed when it was learned that the saloon was to remain fixed and was not to be worked at all during the trip, the reasons assigned being first that the gear for controlling the saloon was not completely adjusted, and second that no opportunity had yet offered for the man controlling the hydraulic gear to obtain that practice in working the machinery which is naturally essential to a satisfactory result. These are, of course, good reasons for leaving the saloon fixed, and we think that the company acted wisely in not working the saloon at all rather than run the chance of

working it unsatisfactorily. Trials of such a nature are far better made in private, as first experiments of this nature cannot be expected to be all successes, and the impressions of public failures are not easy to remove. Whether or not it would not have been more judicious to have postponed the public trial until the swinging saloon was ready to be shown in action is, however, another question, which it is scarcely necessary to discuss here.

Luckily there was really no want of a swinging saloon. With the exception of a slight fog at starting the weather was all that could be desired by a landsman making the Channel passage, while the sea was so calm and the "Bessemer" so steady that none but the most exceedingly qualmish were likely to suffer inconvenience. Under these circumstances the passengers, if they were disappointed in not witnessing the working of the swinging saloon, had at least the satisfaction of being able to appreciate the numerous comforts with which the "Bessemer" abounds—comforts which appear all the greater to those familiar with the accommodation existing on board the ordinary Channel steamers.

We have so recently published descriptions of the chief features of the "Bessemer" that it will be quite unnecessary for us to enter into any detailed account of the vessel here. We may mention, however, for convenience of reference that she is 350 ft. long over all, and 40 ft. actual beam, there being, however, a row of overhanging private cabins down each side between the paddle-wheels, which increase the apparent beam to 54 ft. On deck the length is 270 ft., the low pointed ends which form such a prominent feature in the design making up the remainder of the length. The "Bessemer" is propelled by two pairs of oscillating engines driving feathering paddles 30 ft. in diameter, the two pairs of wheels being situated at a distance of 106 ft. apart from centre to centre, with the swinging saloon between them. The after wheels have, of course, to act upon water which has been previously put in motion sternward by the forward wheels, and hence the former wheels run slightly quicker than the latter. On May 8th the difference in speed of the two pairs of wheels was almost exactly two revolutions per minute, the former wheels making 25½, and the aft wheels 27½ revolutions per minute for the greater part of the trip. The difference in speed of the two pairs of wheels was thus about 8 per cent.

The engines of the "Bessemer" were put on board before the vessel was launched, and to this probably is, to some extent, to be attributed their present state. At all events they are at present, to use a workshop term, considerable "out of truth," this being particularly the case with the pair which were aft during the run from Dover to Calais, and the result naturally being hot bearings. Apart from the defect just mentioned the engines are of plain substantial design, and we trust that they will eventually be put in proper condition. As regards the pressure of steam maintained, state of the vacuum, and indicated power developed during the trip we have no data, and we believe in fact that the engines have not yet been subjected to any regular trial to prove their capabilities.

On May 8th the run from Dover to Calais was made in an hour and thirty-three minutes, and it unluckily terminated by the vessel destroying a portion of the western pier of Calais. As those familiar with Calais harbor well know, the chief pier is situated on the eastern side, the western pier being a much lighter structure. There was a strong tide setting eastward across the mouth of the harbor; and the "Bessemer" was accordingly made to approach the mouth slightly from the westward, port helm being given to cause her to enter the harbor. As she came between the piers the helm was, we believe, steadied and then placed to starboard, but as the vessel lost way the effect of the starboard helm was unnoticeable, and under the influence of the transverse current the stern still paid off to the eastward and the bow to the westward, the result being that the vessel ran into the western pier, completely clearing it away for some 100 ft. or so. The shattering of the pier timbers was a mere trifle to the "Bessemer," the shocks experienced on board being scarcely perceptible, while the only damage the vessel sustained consisted in the removal of a few splinters from the sponsons at the bow and

the carrying away of the foremast in consequence of the pier coming in contact with the wire rope stay. A few minutes after the disaster the "Bessemer" was laid alongside the eastern pier without difficulty, and after partaking of a luncheon provided at Calais station, her passengers proceeded on their way to Paris by special train.

The behavior of the "Bessemer" in entering Calais Harbor has naturally given rise to grave doubts as to whether or not the vessel will be ever placed regularly on the Dover and Calais service. She has now paid three trips to Calais, and on two occasions out of the three she has come into contact with the piers, the entrance on the second occasion being made without difficulty. So far, too, she has had the benefit of fine weather, and how she can be got into Calais with a high sea running has yet to be proved. Her commander, Captain Pittock—well known for his experience in the Channel service—is, we are certain, able to do all that can be done in the matter, but whether further experience will enable the vessel to be successfully handled in such a harbor as that of Calais has yet to be proved. A report has been circulated in some quarters that on May 8th the hydraulic steering gear (Brown's patent) did not act properly at the critical moment; but for this report there was, we have every reason to believe, not the slightest foundation. The gear, in fact, appears to be all that can be desired. It is to be remembered, however, that with this, as with other mechanical steering gears, the motion of the rudder is not absolutely synchronous with the motion of the steering wheel. The former follows the latter faithfully, but it follows it at a very brief interval of time—an interval not noticeable in fact under ordinary circumstances, but of importance perhaps under certain conditions. This being so, it would, we think, be an advantage if there was provided a tell-tale worked from the rudder and showing the actual position of the latter, this tell-tale being situated so that it could be readily seen by the captain or officer conning the vessel, who would thus have positive information afforded him as to the helm which was being given. With a long, shallow vessel such as the "Bessemer," the helm necessary to effect any desired movement has, of course, to be given earlier than it would be with a shorter vessel, and how much earlier is a mattter which only experience can determine, so that it is quite possible that further practice may materially improve the control obtained of her movements in a narrow entrance and under the action of cross currents.

Another point yet to be determined is the effect of the bow rudder. Up to the present time no experiments have been made on the effect of employing the rudder situated in what is for the time being the bow, to assist that astern; but we think that some trials of this kind should be made, and are inclined to believe that under the influence of cross currents the action of the bow rudder would be especially beneficial. This, however, is—like the other points to which we have referred—one on which it is useless to theorize, as it is one regarding which experience alone can give information of value. In leaving this subject for the present we may remark that when fairly under way, the "Bessemer" answers her helm well, and there appears no reason whatever to grumble regarding her steering qualities so long as she is moving through the water at a fair speed.

The return trip was made on May 10th, a special train conveying the passengers from Paris to Calais, and a start being made from the latter place to Dover, at 3 p. m. The run from the actual start at Calais to the vessel being laid alongside at Dover was made in 1 hour and 46 minutes, and the run from pier head to pier head in 1 hour and 44 minutes. The "Bessemer" was not turned for the return trip, and the end which on May 8th was the bow was thus on May 10th the stern, and *vice versa.* The difference between the speeds of the two engines was the same as during the outward passage, the actual speeds during the trip being 26 per minute for the pair which were for the time being the forward engines, and 28 per minute for those aft. The bearings proved to be in better condition on her return trip, and although they still heated, the heating was very much less than during the outward trip, and it was necessary to run water on them. On her arrival at

Dover the vessel was brought alongside the Admiralty Pier in a manner which elicited from the passengers three hearty and well-deserved cheers for Captain Pittock, and shortly afterwards a special train conveyed the passengers to London.

Thus ended the first public trial of the "Bessemer"—a trial which was certainly not without interest, although the great feature of the vessel, namely, the swinging saloon, remained untested. The weather, too, was so fine that the sea-going qualities of the vessel were but very little tried; but there is, nevertheless, every reason to believe—judging from such experience as has been already gained—that they will be satisfactory. As regards speed the prospect is not so promising, the times occupied in the runs on both trips showing that the "Bessemer" is at present certainly not a fast vessel.

To what extent this result is to be attributed to the excess of draught above that originally intended, or how much may be due to the non-development by the engines of the proposed power, it is at present impossible to say; but it is much to be hoped that such experiments may be carried out as may afford some information on this head, as any data of this kind referring to a vessel of the peculiar build of the "Bessemer" have a special interest. We shall, no doubt, before long have more to say regarding the "Bessemer" and her capabilities; but in taking leave of her for the present it is only just to add that whatever speed she may ultimately attain and whatever may be the results of the trials of the swinging saloon, the vessel offers admirable accommodation for passengers, and the comforts which she affords can scarcely fail to be appreciated by the traveling public.

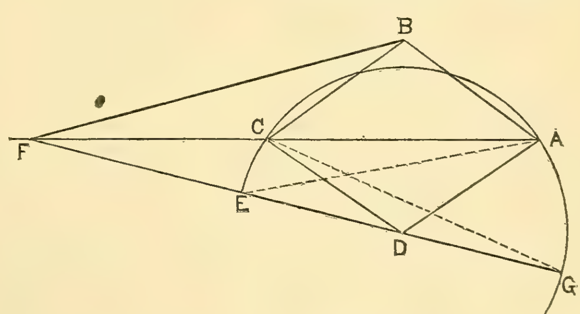
AN ANALYSIS OF THE PEAUCELLIER COMPOUND COMPASS.

By WALTER SCOTT.

Written for Van Nostrand's Engineering Magazine.

Having constructed a Peaucellier Compound Compass, and being compelled to work out for myself the formula for using it, I submit the result for the benefit of others.

Let P B C D A, Fig. 1, represent the outline of a "Positive Cell" instrument, consisting of the equilateral cell A B C D A, and the connectors B F, D F, of equal length. From the construction



of the figure, the points F, C, A, are in the same right line. Let F A=V, F C =V′, F D=F B=L, and a side of the inner cell = l. With D as centre and radius = D C=D A, describe the semicircle E C A G, and produce F D to G. Draw C G, A E. The angle F A E, F G C, being measured by the same arc, are equal, and since the $<$A F E is common the triangles F G C, A F E, are equiangular and similar, hence the proportion

$FC : FG :: FE : FA$:–FC, $FA=FG$, FE.

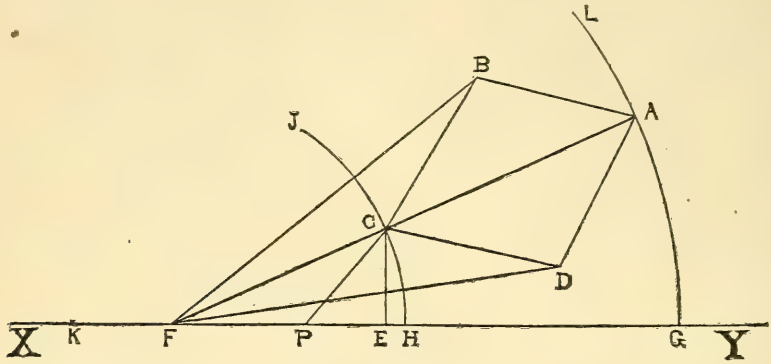
But $FC=V'$, $FA=V$, $FG=L\times l$, $FE=L-l$, hence

$$V.V'=(L+l)\ (L-l)=L^2-l^2,$$ that is,

the product of the arms FA, FC, is constant, and equal to the difference of the squares of a side of the greater and lesser cell.

If the point F be fixed as a fulcrum, and the point C be compelled to follow any curve given by its equation and relative to the point F, the curve described by the point A may be determined.

Let X Y represent the co-ordinate axis, and the point P the origin of the curve H C J in which C is constrained to move. Let the curve G A L, described by the point A, be referred to the fulcrum F as origin.



Let the radius-rector $FA=V$,
" " $PC=v$,
" variable angle $AFG=d$,
" distance $FP=a$.

Then $$FC=\frac{L^2-l^2}{V} \qquad (1)$$

$$CE=FC,\ \text{Sin.}\ d=\frac{L^2-l^2}{V}\ \text{Sin.}\ d$$

$$PE=\sqrt{\overline{PC}^2-\overline{CE}^2}=\sqrt{v^2-\frac{(L^2-l^2)^2}{V^2}\text{Sin.}^2 d}$$

$$FE=FP+PE=a+\sqrt{v^2-\frac{(L^2-l)^2}{V^2}\ \text{Sin.}^2 d}$$

$$FC=\frac{FE}{\text{Cos.}\ d}=\frac{a+\sqrt{v^2-\frac{(L^2-l^2)^2}{V^2}\ \text{Sin.}^2\ d}}{\text{Cos.}\ d} \qquad (2)$$

From eqs. (1) and (2) $$\frac{L^2-l^2}{V^2}=\frac{a+\sqrt{v^2-\frac{(L^2-l^2)^2}{V^2}\ \text{Sin.}^2\ d}}{\text{Cos.}\ d}$$

Reducing and arranging this equation we have

$$V^2+2\ V\frac{a(L^2-l^2)}{v^2-a^2}.\ \text{Cos.}\ d=\frac{(L^2-l^2)^2}{v^2-a^2} \qquad (3)$$

which is the general polar equations of the resulting curve G A L. From this general equation may be found the equations corresponding to any given generating curve.

If the generating curve is a circle with centre P and radius $PH=r$, the radius vector PC becomes constant and equal to r, and equation (3) becomes

$$V^2+2\,V\ \frac{a(L^2-l^2)}{r^2-a^2}\ \text{Cos.}\ d=\frac{(L^2-l^2)^2}{r^2-a^2} \qquad (4)$$

The polar eq. of circle of radius R, passing through G, and referred to F as origin, is

$$V^2+2\,V\left(R-\frac{L^2-l^2}{r+a}\right)\ \text{Cos.}\ d=2\ \frac{L^2-l^2}{r+a}\ R-\frac{(L^2-l^2)^2}{(r+a)^2} \qquad (5)$$

Comparing eqs. (4) and (5) it appears that eq. (4) is the eq. of a circle whose radius $=r.\dfrac{L^2-l^2}{r^2-a^2}$, hence if the point C moves in a circle whose radius $=r$, the

point A will describe a circle whose radius

$$R = r.\frac{L^2-l^2}{r^2-a^2} \qquad (6)$$

In eq. (6) if $r=a$, the value of R becomes infinite, showing that the resulting curve G A L becomes a straight line. Hence by causing the generating circle to pass through the fulcrum the famous problem of parallel motion is solved.

When r is greater than a, R is positive, and the resulting circle will be concave toward F and enclose it.

When r is less than a, R is negative, and the resulting circles will be convex toward F, and fall outside.

If in eq. (4) we make $d=0$, we have $V=\frac{L^2-l^2}{r+a}=FG$, the distance from the fulcrum at which the curve cuts the axis.

If the length of the radius bar P C be fixed the required length of F P can be found necessary to give the resulting curve any given radius, or, conversely if the distance F P is fixed the required length of radius bar can be found. From eq. 16

$R=r.\frac{L^2-l^2}{r^2-a^2}$, from which we find

$$r=\frac{(L^2-l^2)\mp\sqrt{(L^2-l^2)^2+4\ R^2\ a^2}}{2\ R}$$

$$a=\sqrt{\frac{R\,r^2-r\ (L^2-l^2)}{R}}=\sqrt{r^2-\frac{r}{R}\ (L^2-l^2)}$$

If the sides L, l, are respectively 15 and 5 inches, and the radius bar $r=10$ inches, then $a=\sqrt{100-\frac{2000}{R}}$ inches. If R=200 inches, $a=9\frac{1}{2}$ inches, nearly.

If the generating curve H J is an Ellipse, Parabola, or any other plane curve given by its equation referred to P_1, the resulting curve G L can be determined in the same way, and, conversely, if any given curve G L is required to be traced by A, the generating curve necessrry to develop that curve can be found.

THE ORES OF IRON CONSIDERED IN THEIR GEOLOGICAL RELATIONS.*

From the "London Mining Journal."

In addressing an audience like this Institute, composed of men to whom the subject matter is familiar, the lecturer has the advantage of being able to dispense with most of the usual introductory explanations. I will, therefore, with the concurrence of my hearers, assume that it is unnecessary to dwell upon the special characters of the different ores of iron, further than to accentuate those in particular upon which my later statements and arguments in to-night's discourse will mainly depend, omitting the discussion of certain silicates, rarely employed for smelting, and of iron pyrites, the recent technical history of which has introduced to us a new purple ore on a large scale. The ores of iron to which I would invite your present attention are simply the oxides, as met with *per se*, or combined with water, or with carbonic acid—the substances, in fact, which form the great bulk of the material employed for the production of the metal.

When we observe the various results of analysis, or even carefully look into the actual samples of ore, there are often anomalies noticeable where not expected, often two or more kinds mingled together, and giving intermediate results; but I hold it not the less desirable that, as far as possible, we should fix the characters of certain species, hold fast to them through their sundry minor variations, and learn how to follow the clue when these substances are found to pass distinctly from one specific condition to another. I would, therefore, pass under review these important ores, to impress their individuality on the memory, and would then consider some of the changes

* Read before the Iron and Steel Institute, by Prof. Warington W. Smyth, F. R. S.

which nature in many cases has wrought in them, and which sometimes may even need to be noticed in the smelting process, but which very generally will have to engage the attention of the explorer and the miner.

Magnetite.—First in order, if we omit from the elementary metal, which, as such, is a rare and often disputed constituent of the earth's crust, we recognize magnetite, or magnetic iron ore, by its octahedral crystallization, often taken partially or entirely the form of the rhombic dodecahedron, but even when almost compact betraying its crystalline form by the brightness of the triangular faces; further, by its black color, and black streak, and its magnetic property after showing polarity.

This mineral, $Fe\,O + Fe_2\,O_3$, with 72.41 per cent., when pure, is the fine rich ore which Dannemora in Sweden, Arendal in Norway, and several other mines in Scandinavia, have worked with great success for centuries from elongated deposits which are neither lodes nor true strata. It is mainly this ore which forms the vast mass at Gellivara, in Lapland, apparently on a larger scale than any other known agglomeration of iron ore; this it is also which is the chief constituent of the remarkable protrusions boasted of by the Uralian metallurgists, the Katschkanar, the Blagodat, near Kuschwinsk, and the Vissokaya Gora. In Italy, fine examples of magnetite are those of Traversella, in the Piedmontese Alps, and that of Cape Calamita, in the Isle of Elba. In North America, the older stratified rocks, both Lawrentian and Huronian, in Canada, as well as in New York and New Jersey, abound in strips, beds, and masses of magnetite, which are concordant with the stratification, and, though by no means uniformly rich, are sometimes wondrously massive. These have been opened out in hundreds of mines, and are, doubtless, destined to play a great part in the iron trade of the United States.

In Great Britain, a few localities can only be quoted as offering magnetite in workable quantities. A small vein near Penryn, in Cornwall, and another or two near Roche, and, perhaps, that of Ballycoog, near Arklow, ought to be available in favorable times; while a singular series of several successive beds exist at Hey Tor, near Bovey, in Devon, which has only now in these last few weeks been placed in working position. (Mr. Smyth here submitted a section of these remarkable crystalline deposits, as showing on the line of cross-cut level a thickness worthy of attention, and a mode of occurrence bearing strong analogy to some of the Scandinavian mines.)

The minutely crystalline magnetite, which occurs in the north flanks of Aran Mowddy and of Cader Idris, in North Wales, has never yet been opened out with perseverance, and the objection to some of it, that it is pyritous, is to be met by more careful selection.

Hematite.—The second species is the well-known hematite, termed specular ore, or oligist when crystallized, red or kidney ore when in a compact or fibrous condition. This substance $Fe^2\,O^3$, with 70 per cent. of iron in its state of highest purity, too well known to need description, and an important ingredient in the trade of most of the ironmaking countries, is distinguishable in most cases instantly if not by its external aspect, by the blood-red streak, which is sometimes difficult to produce on surfaces as hard and as smooth as polished steel, will appear even though the color of the outside be purple or black. The value of this ore, so little recognized thirty years ago, is now too well known for me to enlarge upon. Its strange occurrence in Furness and near Whitehaven has been well described in the pages of your journal, and a very curious parallel to the northern mines may be found on a smaller scale in the numerous deposits, partly of red and partly of brown hematite, which have for years been worked in the Mendip Hills.

I have to thank the proprietors and agents of two of the most remarkable of these mines for enabling me to place before you to-night the plan and section of the Roanhead and Park doposit, and those of the Hodbarrow mine. There could not be better examples of the entire irregularity of form assumed by these vast masses, of their great productive capability, and of the well-merited success due to the unsparing use of the boring rods.

In our western districts, as near St. Austell and at Exmoor, hematite occurs in veins, not generally large, but exhibiting

some splendid ores, and showing, where they intersect the clay-slates, an analogy with the rich district of Siegen in Prussia, also situated on the rocks of the Devonian system.

There are cases in which these ores are certainly of a bedded character, as in Canada, and at La Marquette in Michigan, where very extensive workings have proved certain strata, mostly made up of this ore, to be from 50 ft. to near 100 ft. in thickness. Probably those of Bilboa may be thus stratified. The Americans seem mostly to ascribe an intrusive origin to their great masses of red ore in Missouri, the well-known Pilot Knob, and Iron Mountain; and the magnificent displays of ore in Elba, some seven in number, occurring in a straight line, are regarded by numerous authors as of volcanic origin.

In fact, when observers have been familiar with the marvelous production of crystallized specular iron by sublimation from the neighboring volcanic vents, it is easy to lean to the belief of its being connected with the volcanic influences in Elba.

Bauxite and Wo-ehnite.—The curious ores to which the names of Bauxite and Wo-ehnite have been given, in which alumina, Al^2O^3, take the place of much of the sesquioxide of iron, deserve special mention, from the fact of the Irish variety being so largely employed in the smelting of hematites. Mr. Snelus has kindly supplied me with analyses of some of these ores in practical use, which, with the percentage of 58, 34.37, and 28.93, of peroxide of iron, contain respectively 17.89, 39.20, and 45.75 of alumina.

Turgite.—Next, we have an ore called Turgite, after the mine of Turginsk, in the Ural Mountains, $2\ Fe\ O^2+H^2O$, an oxide of iron, with 5.3 per cent. of water, of brownish color, but with bright red streak; otherwise with fibrous structure and mammilated surface, looking much like the botryoidal hematites. We know but little about this species, yet it doubtless occurs largely among the brown ores which come to the furnace. It is quoted as found at divers European localities, especially Horhausen in Nassau; and it has been met with at the Restormal Mine, in Cornwall. A compact black ore now being raised at that mine, gave to Mr. Ward, of Dr. Percy's laboratory, only 3.25 per cent. of water.

Go-thite is the name generally given to the definite compound $Fe^2.O^3+H^2O$, in which 10 per cent. of water is added to the ferric oxide. One of the varieties, Lespidverokite, is translucent and red by transmitted light; another "needle iron ore," brilliant, but only slightly translucent; a third, wood iron, opaque and fibrous; a fourth, brown or black ore, opaque and with no regular structure; but, from the splendid prismatic crystals of Lostwthiel downwards, all these varieties have a brown streak. The most notable examples of these ores in our own country are at the Restormel Mine, in Cornwall, on Exmoor, on the Brenden Hill, in the Mendip, near Bristol, and in the Forest of Dean; but there are very numerous places, at home as well as abroad, where, amidst the ores called in the large scale brown iron, or brown hematite, a portion will prove to be this monohydrate, whilst other parts of the same deposit may, very likely, belong to the next following species. The name of stilpnosiderite has been given to a mineral with a lustrous pitchy fracture, but it is somewhat uncertain as to whether it belongs to the above-named division.

Limonite, $2\ Fe^2\ O^3+3H\ ^2O$, with iron 59.9, and water 14.4 per cent. A large proportion of the "brown iron ore," or that which gives a brown streak, belongs to this series, but both the external contour and the structure are very variable. The fact of the brown ores being often met with in the shallower parts of repositories, which may contain other substances in depth, is an explanation of their having been largely explored and worked from a very early period. Thus, as a stratified rock limonite it may sometimes in great thickness be followed downward a long way without change, as in the mines near Elbingerode, in the Hartz, or it may change downward into the impure carbonate, as in the Lias and Oolitic strata. When, in veins, it will commonly be found to constitute a sort of gassan or iron-hat, fated to yield to other minerals in depth.

In the Alston Moor district, hitherto but little worked, it is observable that the "rider" of the lead lodes often shows itself at surface in a great mass

of brown ores; and similarly, in the central part of Cornwall, between Par Station and Ladock, a number of lodes, apparently continuous in their course, with veins bearing elsewhere copper and tin ores, carry, as they approach, and, in some cases, enter the granite rock, brown ores in considerable abundance.

To illustrate the different conditions of hydration and admixture in brown ores from the same locality, I am enabled, by Messrs. Snelus and E. Jackson, to compare two examples of the ore so largely imported from Porman, near Carthagena:

	No. 1.	No. 2.
Peroxide of iron	83.80	74.85
Alumina	.50	3.00
Oxide of manganese	Trace	0.83
Lime	——	1.69
Magnesia	——	0.55
Silica	1.50	8.60
Sulphur	.20	0.21
Phosphoric acid	.07	0.14
Combined water	14.00	10.17
	100.07	100.04
Metallic iron	58.6	52.40

No. 1, a particularly lustrous, stripy ore, would thus approach limonite; No. 2, Gothite in its composition.

Xanthoriderite, or yellow iron ore, $Fe^2O^3+H^2O$, with 18.4 per cent. of water. This ore is of a yellowish color, sometimes in silky fibres and needles, in other cases more like an ochre; but it is cited definitely from only a few localities; and from the character of the occurrence, so commonly in successive incrustation, it is difficult with many of the substances called "morass," or "bog iron ore," etc., to feel assured where the line should be drawn.

Chalybite, Siderite, White Iron Ore, Carbonate, Spathic, Spathose, or Sparry Iron. FeO, CO^2, with 62.1 of protoxide of iron. Such a percentage would give 48.22 of metallic iron; but this is an ore which almost invariably contains, in lieu of some of the iron, a notable amount of manganese, calcium, or magnesium. The rhombohedral crystallization and the crystalline structure are sometimes minutely, but often largely lamellar, both outer and inner planes often curvilinear, with its light shades of color so readily heightened by exposure, these are tolerably distinct external characters. It is only, however, within the last twenty-five years that inquiries after steel irons, and more recently after the means of making spiegeleisen, have attracted attention to it in this country, and have led to extended observations like those read by Mr. Smith to your Institute a year ago. The late Mr. Charles Attwood was the first to utilize the considerable quantities of this mineral present as "rider" in the ironstones of many of the lead mines in Weardale and other parts of the North. In the granite of Foxdale, in the Isle of Man, in the great cross-course lead lode of Frank Mills in Devon, and in many of the Cornish mines, the admixture of chalybite with other ores is often on a large scale, but its value is commonly marred by difficulties of carriage. More important is the range of veins occupying a length of some 30 miles in Somerset and North Devon, from the Ebbw Vale mine of Raleigh's Cross westward, to near Ilfracombe. Nor can I omit to mention the fine lode of Perran, sometimes 100 ft. across, if taken horizontally from wall to wall, where workings, commenced in brown ore, have opened downwards, at depths of from 30 ft. to 120 ft., into large masses of chalybite.

The varieties of ironstone in which the carbonate is mingled with a very variable amount of clay, of lime carbonate, or of carbonaceous matter, are thoroughly well-known to my hearers from their wide diffusion over this country, and their commercial importance. They are, in fact, objects of more interest to the smelter than to the mineralogist. Certain of these, as the celebrated Cleveland ore, date their employment from a very few years ago; others, like the dark pisolitic masses of the pulverzoic schists of Anglesey and North Wales, have hitherto met with but little attention.

Let us now, in order to see more clearly the relationship between these several oxides, examine a few typical specimens, taken from localities where the development may be studied on a large scale. I place on the table a piece of what looks like chalybite or spathic ore, from Hüttenberg, in Carinthia; it is covered with large rhombohedral crystals characteristic of that ore, and through the mass may be traced lines showing the tendency to rhombohedral cleavage. But it is chalybite no longer; the brown streak,

the presence of water, and the percentage of iron, prove it to have been changed into brown ore. Here is a fragment from the lodes of the Deer Park in Exmoor; the cellular mass is pervaded by lines still exhibiting distinctly the rhombohedral structure, but the rich brown color, and the innumerable array of brilliant needles of Göthite, show that this, too, has lost its carbonic acid, has acquired oxygen and water, and actually become a different substance. The first stage of the change may be observed in heaps exposed in the shaft tips even for a few months; a brown tint, heightening with time, takes the place of the yellowish grey, and shows that a chemical action attacks the exterior and proceeds towards the interior. Similarly, at Raleigh's Cross, that well defined lode, in places over 20 feet in thickness was found at from 25 to 30 fathoms deep (vertically) to yield lumps of cellular ore, with kernels of undecomposed spatic, and thence down to the bottom of the mine, this latter ore in greatly increased proportion. In the great Perran lode, near Truro, the entire mass, sometimes for a few feet in depth, in other places down to 10 or 20 fathoms, is proved to consist of brown ores, which then begin to show nuclei of undecomposed chalybite; and lastly, solid masses of that mineral.

It has been argued by some that the change commences with the formation of the more hydrated species, and passes through successive stages to those with the least amount of water; but on this point the evidence is as yet defective.

The brown ores are undoubtedly (for one may watch the process in old workings) formed by another series of changes, from pyrites through the sulphate of iron. The crystals of brown ore, in the form of pyrites, are among the best known pseudomorphs, and there are localities which invite the inference that this action has taken place on an important scale.

Let us now proceed a step further. It was long since argued by Haidinger, that red ore is a pseudomorph after brown ore, and many instances were cited to prove that this change may generally be proved to have taken place. Unfortunately, the most notable example described, was that of specimens from Restormel. The highest authorities were called in to aid in the decision. Gustav Rose crystallographically showed that the forms of the crystals were those of Göthite; Rammelsberg proved that the substance was pure anhydrous oxide. I fear, however, that the whole phenomenon arose from the ingenuity of a roguish mineral dealer, who, by exposing the Gothite to a suitable heat, expelled the water, and thus manufactured deceptive specimens. But the fact is better borne out in other cases, and though difficult to prove in hard fragments, it has been shown by Morgans that a good deal of red ore was found in shallow levels of the Raleigh's Cross vein, which may probably have passed through the intermediate hydrated stage.

If we now examine a specimen from Bearland Wood, on Brendon Hill, another from Roger's lode, Exmoor, a third from the Eiserne Haardt, by Siegen, and a fourth from Somorrostro, at Bilbao, all analogous, we shall notice: first, that the large crystals are the rhombohedrons of chalybite; secondly, that the distinct cleavage of that mineral permeates the entire mass; thirdly, that the substance is pure red ore; and, fourthly, that this last crystallizes out boldly as specular. In all these cases, therefore, and innumerable others, even to a batch of ore brought by the indefatigable Livingstone from Central Africa, the hematite has indisputably been originally deposited as chalybite.

I dare not venture, in the present brief sketch, upon the vexed question of the original deposition of our great northern masses of hematite, although strong arguments for their having once been chalybite may be deduced from the occurrence of mountain limestone fossils turned into red ore. The half-way stage may be seen on the north side of Cross Fell, where, at Fox-fold, I have obtained fossils, now brown ore, which must in all probability have been changed *in situ*, through the intermediate stage of the carbonate.

There is still a last change of condition among the oxides of iron to be noticed. Is it not a significant fact, that magnetite is characteristic of the older formations of those bodies of rock which have, during the longest period of time, been exposed to the influences which bring about metamorphism and change of

substance? In the Perran lode small portions of magnetite have been found among the brown ores near the surface. In some of the Cornish copper lodes, notably in the Fowey Consols, specimens of magnetic ore have occurred, which look very much as if they had been carbonates. Among the beautiful red ores of Siegen, small grains of magnetite appear to testify to a partial change; and in the classical case of the mine, Alte Birke in Siegen, a singular black rather powdery substance, "eisenmulm," of which an example is placed before you, shows how the ore of the mine, in some places chalybite, in others red ore, is changed into an earthy magnetite. This, it is true, has been by some explained by the contiguity of a dyke; but without dwelling on the opposing arguments of Birchof, there appear to be sufficient grounds for believing that, in many cases at least, this last change in the degree of oxidation may be produced by the ordinary action of natural causes.

REPORTS OF ENGINEERING SOCIETIES.

Society of Engineers.—At a recent meeting of the Society of Engineers, a paper by Mr. Ernest Spon on "The Use of Paint as an Engineering Material" was read. The author, in the first place, considered the necessity for the use of paint, and then noticed the composition and characteristics of the pigments usually employed by engineers. White lead, he observed, should be of good quality and unmixed with substances which may impair its brightness. It is usually adulterated with chalk, sulphate of lead, and sulphate of baryta, the latter being the least objectionable. Zinc white is not so objectionable as white lead, but is dry under the brush and takes longer in completely drying. Red lead is durable and dries well, but should chemical action commence, it blisters and is reduced to the metallic condition. Antimony vermilion was suggested by the author as a substitute for red lead, and its qualities enlarged upon. Black paints from the residual products of coal and shale oil manufacture, and oxide of iron paints are generally used for ironwork, for which purpose they are peculiarly suited. Allusion was also made to anti-corrosive paints, and to those containing silica. Referring to the oils used in painting, the author stated that linseed oil was by far the most important, and that its characteristics deserved careful study. It improves greatly by age, and ought to be kept at least six months after it has been expressed before being used. It may be made a drier by simply boiling, or by the addition of certain foreign substances. Nut oil and poppy oil are far inferior in strength, tenacity, and drying qualities to linseed oil, and are used to adulterate the latter. The author noticed the driers employed, and alluded to the properties and means of testing the purity of spirits of turpentine. He then dwelt at length upon the mixing and practical application of paint to new and old woodwork, the preservation of cast-iron by means of Dr. Smith's pitch bath, and the cleansing, painting, and care of wrought-iron structures. He stated that when used under proper supervision no better protection could be found for iron structures than oxide of iron paints. He concluded by observing that the real value of any paint depended entirely upon the quality of the oil, the quality and composition of the pigment, and the care bestowed on the manufacture; and that the superiority of most esteemed paints was due to these causes rather than to any unknown process or material employed in their preparation.

At a meeting of the *Edinburgh and Leith Engineers' Society*, held at Edinburgh, a paper was read by Mr. Duncan Menzies, C.E., on the disposal of sewage. After briefly alluding to the methods of irrigation in use among the ancients, both as described by the sacred and profane writers, he proceeded to state the various modes of treatment at present in operation in different parts of England and Scotland. The result of careful observation proved that the application of sewage to land increased the value of the crops to a very considerable extent—land which was let originally at £1 per acre now yielding grass and other crops of the annual value of £30, and even more. Mr. Menzies then proceeded to describe some irrigation works near Craigmillar, which were laid out under his superintendence. The water of the Pow burn, which drains the south of Edinburgh, was led by main drains and cross-feeders on to fields, the soil of which was clay loam, well drained, and the result of three years' experience was that crops of from £17 to £21 per acre had been taken off, the annual value increasing with the longer application of the sewage. This sewage was necessarily very much diluted, as the natural flow in the Pow burn was great in proportion to the number of houses draining into it; but in spite of the weakness of the irrigation water, the result was highly satisfactory.

At the ordinary meeting of the sanitary and social economy section of the *Philosophical Society of Glasgow*, Mr. James M'Intyre, Port Glasgow, read a paper on "A Scheme for Intercepting and Utilising the Sewage of Towns, and Preventing the Pollution of Rivers." His scheme included a sewer led along the banks of the river, having double tanks at intervals between the towns from which the sewage was drained. In these tanks the solid matter would be intercepted, and from them it could be lifted at intervals of several days, and distributed by means of branch lines to the railways, and so to the districts where it was required. Mr. M'Intyre described an application of this scheme to the Clyde, which would serve Glasgow and the towns above it.

Mr. Murray exhibited to the section a model of a self-acting machine for separating and utilising the sewage of Glasgow, in which he

proposed to spread out the stream of sewage going into the machine, so that its course would not be too rapid, and to strain off the solid matter on the way. He proposed also to purify the water by means of filters of charcoal, or some other deodoriser.

In the course of a discussion on the papers, Mr. Deas, C. E., remarked that the fall along the banks of the Clyde was not sufficient for working Mr. M'Intyre's scheme. If he could overcome this and deodorise the water, the plan would be a capital one. Mr. M'Adam said that all attempts to make the solid matter got from sewage of commercial value had failed. Mr. James Brown observed that Mr. M'Intyre's scheme was substantially the same as one which he himself proposed twenty years ago. Mr. Gavin Campbell contended that sifting the solid matter from the liquid in sewage was simply nonsense. The best way to separate the two was by means of lime. Mr. M'Intyre having replied.

Mr. W. P. Buchan described a self-acting sewage gas-trap, a specimen of which he exhibited. The ordinary trap put into water-closet cisterns he showed to be defective, from the fact that the egg-shaped receptacle which was usually filled with water to trap the gas often dried up, and the gas had then free access to the cistern. Mr. Buchan's trap is so constructed that every time the water rises in the cistern a new supply of water rises into the trap, and it is thus kept constantly closed against the ingress of sewer gas by about an inch of water.—*Iron.*

THE AMERICAN SOCIETY OF CIVIL ENGINEERS. —This Society convened at Pittsburg, according to the programme announced last month. We extract from the *Tribune* the following discussions of the meeting of the 10th of June :

With the greatest unanimity of feeling, there is a wide ground for difference of opinion among civil engineers on what is known as the Bridge Question. It is an outgrowth of the bridge accidents of last year, which a committee of bridge builders belonging to the Society of Civil Engineers took into consideration. They brought in a majority and three minority reports, and ever since the bridge business has been a vexed question. The disagreement is as to the means of preventing such accidents. The majority of the Committee favor the adoption of a standard—that all bridges should be built to carry not less than a certain number of pounds per square foot; the number being fixed in tables, with reference to span and the uses to which different classes of bridges are subjected. These tables would require bridges which are unquestionably within the limits of safety. But the opponents of this proposition say that no account is made by it of the difference in iron or other materials. If the best iron, for instance, is by this restriction to be used in the same abundance with the worst, there is no object to be gained by using the best, and the result would be either that the rule would be ignored or inferior materials would be everywhere used. Gen. Ellis, discussing the subject said that the Committee seemed to be unanimous as to the load which ought to be used to test a railroad bridge : two heavy locomotives and a train of cars loaded to the maximum.

Mr. Herschel advocated the plan of subjecting the iron used for bridges to specific tests. The fact that such tests would be applied would cause contractors to furnish good iron. Mr. Clarke, engineer of the Phenixville Bridge, said that Western people were urgent that a standard of strength for bridges should be fixed. But if the State was to select experts to decide upon bridges the whole business would become, too soon, a mere political placer. There was discussion over the mathematics of one of the reports, and they were explained by Mr. Macdonald. But he thought that if the strength of the iron used was to be taken into account, the limit of its elasticity was a far more important factor than its breaking strength ; he named an instance where the former was only one-half the latter.

Mr. Macdonald urged the adoption of the majority report on preventing bridge accidents. He would somewhat modify it, and he proposed that a Committee of three be appointed to report whether legislation on the subject should be recommended.

Mr. Ellis spoke of the difference of iron used in various localities. The English factor of safety in bridges was one-third ; ours only one-fifth. Mr. Herschel said that France, Prussia, England, and some minor European States had adopted laws respecting bridges defining the strain they must bear to the square inch ; since those laws went into force no bridge accidents had happened in those States. The public demand of the engineers of this country a similar protection.

Mr. Richard H. Buel, of New York, not being able to meet with the Convention, sent to the Secretary a paper which was read, containing a severe criticism upon the report of the Committee on Rapid Transit. To this Mr. Collingwood replied that the Committee had not found any practical scheme of rapid transit on a paying basis, but they did not propose to select any one scheme as the best, since some of the plans came from members of the Society. This morning Mr. Wm. H. Searles, of New York, resuming the debate upon this subject, said that an ordinary railroad is built only to accomplish a long journey in a short time; rapid transit requires high speed with stops at frequent intervals. Great loss of power is incident to frequent stops, and where the frequency increases the loss of power is even disproportionately augmented. In the case supposed, the maximum velocity between the stops must be $2\frac{1}{2}$ times the average velocity of the train when moving.

Mr. J. Dutton Steele discussed the inevitable features of rapid transit, which he regarded as necessarily implying an elevated railway and a narrow gauge. Mr. Charles E. Emery thought that even if an endless railroad were not desirable, the system of landing passengers on a moving train by a subsidiary railroad was worth considering. If the friction system was unadvisable, the supplementary road at the side might have its cars drawn by light engines

till their speed equaled that of the rapid train, and then the two trains be coupled at the sides till the passengers to be added or left were transferred.

There was a discussion on the shape of rails, in which Mr. Holley, who knows more about Bessemer steel than any other member of the Convention, gave a lucid explanation of the laws which regulate the composition of rails, depending on the different kinds of strains to which the parts of the rail are subjected.

IRON AND STEEL NOTES.

Tests of the Strength of Iron and Steel.—The importance of the Commission lately authorized by Congress to determine the strength of iron, steel, and other metals, will appear from the following considerations: So undetermined is the safe working load of different metals and of different structural forms that the professional rule is to subject bridges, roofs, and general machinery, to but one-sixth of the loads that are supposed to be great enough to break them. Although this rule is wasteful of material in most cases, it does not insure safety in all. In the fear that structures may be too weak, they are overloaded with costly materials; yet, despite this precaution, bridges, roofs, and floors give way, and machinery is perpetually breaking down.

The problem is by no means a simple one. Because an inch square bar will stand a certain load, it does not follow that each square inch section of every bar will sustain the same load. The resistance of a simple structure formed of bars—for instance the end-post of an iron bridge—is notably changed by no less than seven conditions, namely, the chemical constitution of the material, its temper and initial strains, due to manufacture, the length of the members of the structure, their thickness, their shape, the dimensions of the structure as a whole, and the arrangement of its parts with reference to the number and direction of strains. In other cases, the character of the stress — impact, vibration, or statical load—also changes the conditions of strength. Nor is the ultimate resistance of the material the criterion of safety; it is the resistance within the limit of elasticity. The former is comparatively easy—the latter difficult to determine. Then there is the apparatus for accurately weighing strains reaching to a thousand tons, and for measuring changes of figure under stress to less than the thousandth of an inch. The useful formulation of results, and the deduction of general laws from the numerous phenomena developed, is the crowning feature of the undertaking. These considerations give some idea of the magnitude and importance of the work before the Commission.

Judging from the character of the experts appointed by the President to do this work, we may reasonably expect results of great and far-reaching usefulness. Colonel Laidley, of the Ordnance, Colonel Gillmore, of the Engineers, Commander Beardslee, and Chief-Engineer David Smith, of the Navy, and Prof. Thurston, are not only competent mathematicians and professional observers of the uses and tests of materials, but they are trained experimenters in this very direction. For instance, Colonel Gillmore is the foremost authority, abroad as well as at home, on limes, cements, and artificial stone. General Sooy Smith is an experienced bridge builder and civil engineer, and Mr. A. L. Holley is a mechanical engineer and a practical metallurgist and steel maker.

The work the Commission has laid out is not narrow and incomplete. It involves not merely testing and branding specimens sent in by different makers, (which is very important as far as it goes,) but in several respects it embraces features never before undertaken by Government Boards, or on a comprehensive basis. Two of these features deserve special mention :

First—The combination of chemical and mechanical tests. It is now well settled that the effects of carbon and of the metalloids upon iron, and upon each other in combination with iron, produce as many physical characters as there are uses for iron and steel. Determining the behavior of materials under stress merely proves that substances adapted to various uses are in existence; what these substances are, and how they may be reproduced, is taught only by chemical analysis. Perhaps the highest usefulness of these combined tests will be the development of greater strength, toughness, hardness, and various other resistances to innumerable varieties of stress—the establishment of scientific synthesis in the manufacture of materials, by means of which they may be perfectly adapted to their uses, thus largely economizing cost and promoting safety.

Second.—The testing of structures and parts of structures of the sizes actually employed, and under the conditions of actual service. Few bridges fail because the ultimate resistance of a bar of the iron composing them is unknown to their builders. Many bridges break down because no builder has yet determined by anything short of the breaking down itself, the exact effect of compound strains on compound structures ; and even this does not give the laws of resistance. When a bridge-post, for instance, carries but a sixth of the weight that a specimen of its material will bear, it may fail. The Commission purposes subjecting, in each of their standard forms, whole bridge-posts, and whole sections of bridge chords and whole floors of girders and whole large structures, just as they are used, to destructive stress ; to measure the stress and its effects at each stage, and to deduce laws of resistance which will enable engineers to develop better forms, thus dispensing with an unnecessary margin of safety, and promoting actual safety and economy. In short, it proposes to grapple with these great practical problems just as they are presented, and not to skirmish around them by breaking little iron rods, and then figuring out conclusions in which a small error is magnified at every step.

Such experiments will occupy years of careful work and many thousands of dollars in

money; but what an insignificant percentage this cost will be upon the millions now wasted in overloading on the one hand and in failure on the other. Whatever degree of improvement later years have witnessed in the constructive arts is due to such researches as these, limited and imperfect though they may have been. It is the duty of this commission, and we believe that it will be its privilege, to determine the laws by which the safety and economy of engineering structures are to be largely increased.—*N. Y. Times.*

Organization of the U. S. Board appointed to test Iron, Steel, etc.

President, Lt. Col. T. T. S. Laidley, U. S. A., Commander L. A. Beardslee, U. S. N., Lt.-Col. Q. A. Gillmore, U. S. A., Chief Eng'r David Smith, U. S. N., W. Sooy Smith, C. E., A.L. Holley, C. E., R. H. Thurston, C. E., Secretary.

Standing Committee of the Board.

(A) On Abrasion and Wear—R. H. Thurston, C. E., Chairman, A. L. Holley, C. E., Chief Eng'r D. Smith, U. S. N.

Instructions:—To examine and report upon the abrasion and wear of railway wheels, axles, rails and other materials, under the conditions of actual use.

(B) On Armor Plate.—Lt. Col. Q. A. Gillmore, U. S. A., Chairman, A. L. Holley, C. E., R. H. Thurston, C. E.

Instructions:—To make tests of Armor Plate, and to collect data derived from experiments already made to determine the characteristics of metal suitable for such use.

(C) On Chemical Research.—A. L. Holley, C. E., Chairman, R. H. Thurston, C. E.

Instructions:—To plan and conduct investigations of the mutual relations of the chemical and mechanical properties of metals.

(D) On Chains and Wire Ropes.—Commander L. A. Beardslee, U. S. N., Chairman, Lt. Col. Q. A. Gillmore, U. S. A., Chief Eng'r D. Smith, U. S. N.

Instructions:—To determine the character of iron best adapted for chain cables, the best form and proportions of link, and the qualities of metal used in the manufacture of iron and steel wire rope.

(E) On Corrosion of Metals.—W. Sooy Smith, C. E., Chairman, Lt. Col. Q. A. Gillmore, U. S. A., Cammander L. A. Beardslee, U. S. A.

Instructions:—To investigate the subject of the corrosion of metals under the conditions of actual use.

(F) On the Effects of Temperature.—R. H. Thurston, C. E., Chairman, Lt. Col. Q. A. Gillmore, U. S. A., Commander L. A. Beardslee, U. S. N.

Instructions:—To investigate the effects of variations of temperature upon the strength and other qualities of iron, steel and other metals.

(G) On Girders and Columns.—W. Sooy Smith, C. E., Chairman, Lt. Col. Q. A. Gillmore, U. S. A., Chief Eng'r D. Smith, U. S. N.

Instructions:—To arrange and conduct experiments to determine the laws of resistance of beams, girders and columns to change of form and to fracture.

(H) On Iron, Malleable.—Commander L. A. Beardslee, U. S. N., Chairman, W. Sooy Smith, C. E., A. L. Holley, C. E.

Instructions:—To examine and report upon the mechanical and physical proportions of wrought Iron.

(I) On Iron, Cast.—Lt. Col. Q. A. Gillmore, U. S. A., Chairman, R. H. Thurston, C. E., Chief Eng'r D. Smith, U. S. N.

Instructions:—To consider and report upon the mechanical and physical properties of cast iron.

(J) On Metallic Alloys.—R. H. Thurston, C. E., Chairman, Commander L. A. Beardslee, U. S. N., Chief Eng'r D. Smith, U. S. N.

Instructions:—To assume charge of a series of experiments on the characteristics of alloys, and an investigation of the laws of combination.

(K) On Orthogonal Simultaneous Strains.—W. Sooy Smith, C. E., Chairman, Commander L. A. Beardslee, U. S. N., R. H. Thurston, C. E.

Instrustions:—To plan and conduct a series of experiments on simultaneous orthogonal strains, with a view to the determination of laws.

(L) On Physical Phenomena.—W. Sooy Smith, C. E., Chairman, A. L. Holley, C. E., R. H. Thurston, C. E.

Instructions:—To make a special investigation of the physical phenomena accompanying the distortion and rupture of materials.

(M) On Re-heating and Re-rolling.—Commander L. A. Beardslee, U. S. N., Chairman, Chief Eng'r D. Smith, U. S. N., W. Sooy Smith, C. E.

Instructions:—To observe and to experiment upon the effects of re-heating, re-rolling, or otherwise re-working; of hammering, as compared with rolling and of annealing the metals.

(N) On Steels produced by Modern Processes.—A. L. Holley, C. E., Chairman, Chief Eng'r D. Smith, U. S. N., W. Sooy Smith, C. E.

Instructions:—To investigate the constitution and characteristics of steels made by the Bessemer, open hearth, and other modern methods.

(O) On Steels for Tools.—Chief Eng'r D. Smith, U. S. N., Chairman, Commander L. A. Beardslee, U. S. N., W. Sooy Smith, C. E.

Instructions:—To determine the constitution and characteristics, and the special adaptations of steels used for tools.

RAILWAY NOTES.

Steel Rails for California.—It is gratifying to know that the Pacific Coast, which has never felt the effects of our great panic, is coming to the rescue of the Eastern iron trade. Recently the Southern Pacific Railroad Company of California contracted with the Pennsylvania Steel Company and the Bethlehem Iron Company for 10,000 tons of steel rails—5,000 from each company—to be used in continuing the line of the road south of Los Angeles in the direction of Fort Yuma, the southern terminus of the road, at the junction

of the Colorado and Gila Rivers. The distance by rail from San Francisco to Fort Yuma is 722 miles. At Fort Yuma the Southern Pacific will connect with the Texas Pacific (Col. Scott's road), and farther north, at Fort Mohave, on the Colorado River, another eastern connection is expected to be made in time. The steel rails ordered are to weigh 50 pound to the yard, and the quantity ordered will lay 100 miles of single track, including sidings.

The rails will be shipped to Jersey City by rail, and thence by sailing vessels around Cape Horn to San Francisco. The freight from San Francisco will not exceed $10 a ton, and is expected to be a dollar or two less. The rails will serve admirably as ballast for light cargoes.

We hope that this transaction may be but the beginning of a large trade in steel rails and iron and steel products generally between the east and the Pacific coast. The states and territories of the Pacific slope consume annually about 300,000 tons of iron in all forms, and until they are ready to make their own iron and steel it would certainly be wise for them to buy their supplies from sister states rather than from foreigners. They will thus save money and be better served. Heretofore California has been a large importer of iron and steel products. In the fiscal year ended June 30, 1874, her imports of these articles aggregated $1,555,000.—*Bulletin Iron and Steel Association.*

BRAKE TRIALS.—The Royal Commission on Railway Accidents, which has lately been taking evidence in different towns in the country upon means for diminishing the frequency of disasters on the iron highways of the country, have asked the Railway Companies' Association to make experiments with continuous brakes. The Railway Companies' Association has consented, and a piece of level line on the Nottingham and Lincoln branch of the Midland Railway has been selected. Several continuous brakes will be brought forward for trial—amongst them the Westinghouse, the Barker brake, Clark's chain brake as improved by Webb, vacuum brakes, and others. Mr. Edward Woods, C. E., of Westminster, has been appointed to conduct the trials, and Colonel Inglis, R. E., is associated with him. The experiments commence on the 9th proximo, and we believe every care will be taken to render the tests exhaustive, both for the information of the Royal Commission and for the guidance of railway managers and engineers. To carry out such a series of tests as will settle the question as to which is the best continuous brake, can be no easy matter, but due precautions will, we hope, be taken to secure a good result.

ENGINEERING STRUCTURES.

ENGINEERING PROJECTS IN EGYPT. — An Egyptian correspondent, writing recently, says: "The Soudan Railway is being rapidly pushed forward. Various schemes are also under consideration for the better irrigation of Lower Egypt. One proposal is for the construction of a series of locks and weirs on the existing canals, which during high Nile are so many deep and rapid rivers. Another is for the construction of canals taken from a high level on the river, in upper Egypt, and distributing the water thus obtained over the surface of the Delta. But it must be remembered that, great as is the volume of water in the stream, it is precisely when the river is at its lowest that the cotton crop requires most irrigation. Perhaps, after all, the moderns could not do better than follow the example of the old Egyptians and construct another Lake Mœris as a vast reservoir for the surplus waters; at all events, his Highness has at his command engineering skill second to none in the world."

THE NEW CLYDE GRAVING DOCK.—A new graving dock is being constructed at Saltserscroft, on south side of the Clyde. The contract for the dock was let so far back as 1869 to Mr. William Scott, who constructed the Albert Dock, at Leith, but a variety of causes have prevented the execution of the work. The new dock is 560ft. in length on the floor, with a depth of 22ft. on the sill at high water of spring tides, and 20ft. at neaps. It faces up the river, and will be closed by a caisson, constructed by Messrs. Hannah, Donald & Wilson, engineers, Paisley. The bottom of the dock is of ashlar, slightly convex in cross section, with a gentle fall towards the entrance. The coping and the caisson check of the dock are of granite, and the remainder of the masonry freestone. The pumping station is at the north-west portion of the dock, the contractors for this work being Messrs. Eastons and Anderson, of London. The second dock is intended to be 15 ft. longer than the one which has been finished, its total length being 575 ft. The Parliamentary engineer for the dock was the late Mr. Duncan, whose death soon after the act was passed led the trustees, pending the appointment of a successor, to entrust the preparation of the contract plans and specifications, to Messrs. Bell and Miller, civil engineers, of Glasgow, under whose supervision the works have been carrid out.—*The Builder.*

ORDNANCE AND NAVAL.

AN interesting series of torpedo experiments against the old Oberon hulk has been held in Portsmouth Harbor, under the direction of Captain Singer, of the Vesuvius. The object was to ascertain the respective explosive forces of various preparations of gun-cotton. The weights and distances were in every instance identical. The mine consisted of an outriggar charged with 100 lb. of gun-cotton discs firmly packed. This was submerged to a depth of 10 ft. at a perpendicular distance of 20 ft. or something like 28 ft. from the Oberon's side, the intention of Captain Singer being to make an indentation in the hulk sufficient for the purpose without destroying or sinking the target. The bursting charge consisted of the same weight of solid slabs of gun-cotton fired by electricity.

So far as could be judged from the force of the detonation, and the volume of water upheaved, the superiority would seem to rest with the compressed slabs, but the precise comparative result cannot be ascertained until the Oberon has been examined in detail.—*Engineer*.

BOOK NOTICES.

USEFUL TABLES COMPILED BY W. H. NOBLE, M. A., Captain Royal Artillery. London: 24 mo, paper. For sale by D. Van Nostrand. Price 25 cents.

A very excellent little set of "Useful Tables" containing "Metric Measures of Weight," "of Length," and "of Capacity," with the corresponding British Measures converted into metric system. Also, Tables of Comparisons of Thermometer Scales, Tables of Natural Sines, Tangents, Secants, &c., and Five Figure Logarithms.

CATALOGUE OF THE OFFICERS AND STUDENTS OF COLUMBIA COLLEGE FOR THE YEAR 1874–1875, being the 121st since its foundation. New York: D. Van Nostrand. 1875. Price 50 cents, or if sent by mail, 67 cents.

This the last Annual Catalogue or Register of Columbia College has just been published. It forms a thick octavo volume of 265 pages. It contains a list of all the officers and students in the different Schools of "Letters and Science," "Mines," "Law," and of "Medicine," with general information as to each, a detailed description of each Department of Instruction, with plan of the new Building for the School of Mines, the Course of Study, Rules of Order, Prizes, Scholarships, Officers of the different Alumni Associations, Honor Men, Graduates, Degrees, Scheme of Attendance, Lecture Courses, Text Books, Examination Papers, etc., etc.

A COURSE IN DESCRIPTION GEOMETRY FOR THE USE COLLEGES AND SCIENTIFIC SCHOOLS, by WM. WATSON, Ph. D. 4to. portefolio cloth. London: Longman, Green & Co. 1875. For sale by D. Van Nostrand. Price $7.00

The contents of this work comprise Problems of Position relating to the Point, the Right Line, and Plane, the General Method of Rotations; the Method of Changing the Coordinate Planes; Plane Curves and their Tangents; Curves of Error; Cylinders; Cones; and Surfaces of Revolution; Tangent Planes; Section Planes; Intersection of Surfaces; Spherical Projections; Developable Surfaces; Warped or Skew Surfaces. The text is accompanied by 32 elegant quarto plates engraved by distinguished European artists. The appendix contains 36 stereoscopic views, engraved on steel, by Rigel, of Nuremberg. The latter, many of which are elaborately colored, are designed to supersede for the student the use of the costly models generally employed to illustrate this subject. It is believed and hoped by the author that the work will be found the most completely illustrated practical treatise on descriptive geometry in the English language.

STORMS: THEIR NATURE, CLASSIFICATION AND LAWS. By WM. BLASIUS. Philadelphia: Porter & Coates. For sale by D. Van Nostrand. Price $2.50.

This work will prove an interesting addition to the literature of Meteorlgy, whether it affords sound instruction or not. The author's explanation of his method in beginning his researches cannot be read without feeling respect for the opinions founded on such systematic methods. We remember perfectly the storm in Middlesex County, Massachusetts, whose track the author studied and mapped, and we remember to have adopted opinions at the time, which the author gives sufficient reasons for abandoning. The chart of this storm, which he calls the West Cambridge Tornado, forms a fitting frontispiece to the work, while the description of the debris along its track, and the author's analysis of it, forms the introductory chapter,

The theories of Redfield, Espy & Dove are all discussed and rejected. The views offered as substitutes are urged in a fair spirit and with an abundant knowledge of the physical facts.

The book appears at a good time, the widespread and growing interest in the subject will doubtless insure a wide circle of readers. It possesses one merit wanting in the standard works on Meteorology, and that is convenient size. There is nothing in its dimensions to discourage the general reader from attempting to read this author through; at the same time the maps and other illustrations, without being marvels of art, suggest a clear elucidation of the subject.

PLATTNER'S MANUAL OF QUALITATIVE AND QUANTITATIVE ANALYSIS WITH THE BLOWPIPE. From the last German Edition. Revised and enlarged by Prof. TH. RICHTER. Edited by T. HUGO COOKESLEY. London: Chatto & Winders.

We fear there is a growing disregard of the eighth commandment; at least there is a strong bit of testimony to this effect in this very respectable looking English book. The title page justifies the expectation of a new translation of the celebrated German work, but examination proves it to be an accurate copy, so far as it goes, of the excellent translation by Prof. Cornwall. (New York: D. Van Nostrand, 1872),

The preface is as misleading as the title page. We give it entire.

"A work like the present needs but a short preface. A good book on the Blowpipe has long been wanted in England, and it is because of the increasing importance of Analysis by means of this instrument that I have edited the great work of Plattner.

While staying, last year, at the Freiburg Mining Academy, Saxony, I was so impressed with the perfection to which the use of the Blowpipe has been brought by the German teachers who use Plattner's work as a textbook, that I resolved to give English students the benefit of Plattner's researches.

The first English translation of this work was issued in New York, and I have followed generally the translation of the American edition, omitting, however, some few portions

which I have thought superfluous. I have also omitted the long list of minerals given under each heading, as iron, lead, &c., amounting to several hundreds in the German edition. However useful such lists may be as a mineralogical reference, still they hardly belong to the province of the Blowpipe. The headings of the different combinations, and all the principal minerals, however have been retained, and their characteristics fully described as in the German original. I have added a new drawing and description of a mechanical blowpipe, which is the only one which is at once portable and thoroughly simple and effective. It would not have been a very laborious or difficult task for me to have greatly reduced the size of the book, but I have thought it better, as Plattner may be justly called the father of this department of analysis, to edit the work in its entirety.

In commending the volume to the English student, I need only add that it is by far the most complete work extant on a subject both of growing practical importance and of extreme interest."

Now this preface, brief as it is, is very nearly the sum total of Mr. T. Hugo Cookesley's work in connection with this volume, all the rest is Prof. Cornwall's translation; abbreviated somewhat but otherwise unaltered. There is not the slightest acknowledgment of this latter gentleman's work that we can find in the book, nor is there any mention of his name save in the last two paragraphs of the appendix where "Mr. Cornwall" is mentioned as a person holding some opinions on the subject of qualitative tests for potassa and bismuth.

Even the few definite statements of the preface are affected with a rather large personal equation. "A new drawing and description of a mechanical blowpipe" is referred to as though it were an important alteration of the original work. The fact is, it is only a badly modified diagram of the same instrument described on page 7 of the American edition.

The claim that the book "is by far the most complete work extant" on this subject, is of course simply absurd, in view of the fact that the valuable lists of minerals of both American and German editions are omitted. We can see substantial reasons for suspecting that there is no real person claiming the name of editor, but that it simply is a device of the publishers to evade the responsibility of doing what is characterized in the preface as *following generally* the American translation. The work is just such as could be done at the printer's from a copy of Prof. Cornwall's translation, with the general instruction to omit the lists of mineralogical names and symbols where the liability to error in following copy was greater than usual. No skilled labor in editing higher than this, is anywhere apparent in the volume.

If there is a T. Hugo Cookesley, the reputation he has recently earned is not enviable.

A Grammar of Coloring. By G. Field. New edition, revised. London: Lockwood & Co. For sale by D. Van Nostrand. Price $1.00.

This is one of the re-issues which are being made of a good many of the original treatises comprised in "Weale's Series;" the "Grammar of Coloring" being that of Field, re-edited, with additions, by Mr. Ellis A. Davidson. Field's treatise must not be confounded with his wellknown one on color in the wider sense; the present treatise being an entirely practical one, on the varieties and qualities of the pigments used in coloring, and the media and (to some extent) the processes of manipulation employed. A good deal of what is included under this latter head is supplied by the editor, who gives directions for the preparation of paper, canvas, and other materials for paintng on, the choice and use of brushes, &c.; and also a chapter on the characteristic features of the various styles of ornament; the latter, however, is only of an empirical nature, and not intended, probably, to do more than give a general notion of the matter to decorative painters. Otherwise the book is a most useful *resume* of the properties of pigments, one for reference rather than reading. In re-editing, however, it should have been pointed out that the old division of primary and secondary colors (which, as far as pigments are concerned, is the practically correct one) can hardly be alluded to now without at least a reference to the newer theory on the subject evolved by Professor Church and others, from the study of the combinations of colored rays, instead of pigments, and in which green usurps the former place of yellow as a primary. The point is of more theoretical than practical importance, certainly; but the results arrived at in Professor Church's experiments are too striking to be passed over in any book in which the subject is touched upon.—*Builder*.

Elements of Euclid Adapted to Modern Methods in Geometry. By James Bryce, M. A., LL. D., and David Munn, F. R. S. E. London and Glasgow: W. Collins, Sons & Co. 1874.

The editors of this improved edition of the time-honored Elements of Geometry, which has held its own as a text-book for ages and which is not likely to be superseded, approach their task with profound respect for the venerable author whose work they aim at amending in some degree. Any attempt to supplant it altogether they strenuously deprecate. Not only, they say, has Euclid's great work received the approval of many successive ages, and served to connect the science of the present with that of the past, but even now, in the advanced state both of the Pure and the Applied Mathematics, it is open to criticism on very few points; and with true conservatism they urge the paramount importance of its retention, not only as a common standard of reference, but also as one by which the "purity and rigorous character of geometrical demonstrations shall be maintained, and a true logical sequence kept up in the order in which these are presented to the mind of the student." The improvements introduced are of three classes. An attempt has been made to incorporate in the work certain geometrical methods which have an important relation to those of the

modern analysis, where that could be done without abandoning the strict methods of Euclid; the order of the propositions has been altered in several cases, so as to make the connection between them more apparent; and the proofs have been shortened where that could be done without omitting any link in the chain. Each of the six books used in this manual is followed by an appendix, in which are placed supplementary propositions and a series of theorems and problems for the exercise of the student, gradually increasing in difficulty, and related as far as possible to the order of the propositions.

PRINCIPLES OF MECHANICS AND THEIR APPLICATION TO PRIME MOVERS, &C. By W. J. MILLAR, C. E. London: E. & N. Spon. 1874. For sale by D. Van Nostrand. Price $2.

Mr. Millar, who ably officiated as the successor of Professor Rankine in the period between the death of that eminent teacher and the filling up of the professorial vacancy, has here published a carefully revised abstract of the lectures then delivered by him to Professor Rankine's Class of Civil Engineering and Mechanics. The area occupied by these lectures was an extensive one, including over fifty important branches and a considerably larger number of subsidiary ones, such as water and steam power motors, naval and architectural construction, thermo-dynamics, water supply, &c. To compress this into a small manual requires very considerable power of concentration, and the exercise of great judgment in the elimination of all matters not strictly essential to the subject in hand. In both respects Mr. Millar's book deserves praise; and, on account of the qualities of this kind which it displays, the conciseness and quantity of the information it supplies, and its general correctness, it must take a high place as an important addition to the educational literature of the mechanical arts.

PRINCIPLES OF METAL MINING. By J. H. COLLINS, F. G. S. Collins' Elementary Science Series. London and Glasgow: W. Collins, Sons & Co. 1875. For sale by D. Van Nostrand. Price 75 cents.

This is an excellent compendium of the methods employed in an important industry, and it is the more reliable from being the work of a practical miner. In his introduction, Mr. Collins, although advising the tyro to gather information from books and every other available source, wisely insists that the art of mining must, to a great extent, be learnt at the mine. Still, the practical miner will learn much from such a work as the present, and a manual so complete and popular will be especially serviceable at the present time, when a strong desire is shown by the best of the mining population to attain a scientific knowledge of their profession. Mr. Collins commences with a plain treatise on the geology of the subject, and follows with an exposition of the practical department of his art, describing not only the methods, but also the tools employed, and noting the comparative value of each. Apparatus for draining and ventilation also occupy one or two chapters, and examination questions, a full glossary of terms, and a copious index are appended.—*Iron.*

AN ELEMENTARY EXPOSITION OF THE DOCTRINE OF ENERGY. By D. D. HEATH, M. A. Longmans, Green & Co. For sale by D. Van Nostrand. Price $2.25.

In this book we have a very good elementary exposition of the Doctrine of Energy; perhaps, however, better adapted for the use of schools than for the general public. Indeed, we are told in the preface that the work was developed from a set of lectures given to the senior classes of Surrey County School.

After dismissing the subject of fundamental units, the writer goes on to dynamical energy, a subject which is fully and fairly discussed. The author next proceeds to thermal and other energies, and ends by a brief account of molecular theories. If we have any fault to find, it is that undue preference seems to be given to the British system of units, while the decimal system is overlooked.

The author, as he tells us in his preface, has endeavored to give the young student some conception of the *possibility* of explaining the conservation of energy by the theory that all phenomenal changes are really in themselves changes of motion and position among the molecules or ultimate atoms of substances; and he adds the hope that he has succeeded in presenting this as exhibiting a probable surmise, which may be false without vitiating the doctrine previously developed.

This strikes us as being very well put. The conservation of energy would hold if we imagine the universe to be composed of ultimate atoms, with forces acting in lines between them; but should it be found that this last conception is inapplicable to portions of the universe, as, for instance, the medium which conveys light, nevertheless it does not follow that the conservation of energy does not still hold true.—*Nature.*

THE COMMERCIAL HANDBOOK OF CHEMICAL ANALYSIS. By A. NORMANDY. New edition, enlarged by HENRY M. NOAD, Ph. D., F. R. S. London: Lockwood & Co. 1875. For sale by D. Van Nostrand. Price $6.25.

When the late Dr. Normandy first published his work on Commercial Analysis the Adulteration Act did not exist, and the book was chiefly used by chemical manufacturers and by the small class of practical analysts. Dr. Noad's enlarged edition of the work appears very opportunely, and it will be found to be essential to the analysts appointed under the new Act. It contains, in alphabetical order, a concise list of all ordinary substances which can require to be analysed in connection with food and drink, and in addition the methods of analysing many substances which can only be required in special manufactures, or are only used as drugs. Each article commences with an account of the substance in its pure state; this is followed by a list of the most common impurities or adulterations, and then by the best means of detecting them. The adulterations of some common commodities are somewhat startling; thus, bread may contain rye and barley flour, oatmeal, pea and bean meal,

potato starch and rice flour, while of mineral constituents there may be lime, alum, magnesia, ground soapstone and sulphate of copper. The substances sometimes employed to color sweetmeats, liqueurs, jellies, &c., include some of the most fatal poisons, such as the acetate, arsenite and carbonate of copper, chromate and iodide of lead, and the sulphides of arsenic and mercury. Indeed, we well remember going over a sweetmeat manufactory, and on remarking on the bright yellow color of some large comfits we were told that chrome yellow was employed to produce it, our informant evidently having no idea that the substance is a most virulent poison. A long article is devoted to the adulteration and fabrication of wines, and the "plastering" and "fortifying" of sherries is discussed at length. In all cases the most recent results are given, and the work is well edited and carefully written. A glossary at the end of the book will be found useful both to the analyst and the student.—*Nature.*

MISCELLANEOUS.

The exact period when the art of manufacturing glass was first introduced into England is not easily determined. It is said to have been brought into the country in 1557; and the finer sort of window glass was then made at Crutched Friars, in London. The first flint glass made in England was manufactured at Savoy House in the Strand, and the first plate glass for looking glasses, coach windows, etc., was made at Lambeth in 1673, by Venetian workmen brought over by the Duke of Buckingham. The date of the introduction of the art of glassmaking into Scotland is more easily determined, because of more recent occurrence. It took place in the reign of James VI. An exclusive right to manufacture glass within the kingdom for the space of thirty-one years was granted by the monarch to Lord George Hay in the year 1610. The right his lordship transferred in 1627, for a considerable sum, to Thomas Robinson, merchant tailor, London, who again disponded of it for £250 to Sir Robert Mansell, Vice-Admiral of England. The first manufactory of glass in Scotland, an extremely rude one, was established at Wemyss, in Fife. Regular works were afterwards established at Prestonpans and at Leith. A bottle was blown at the Leith glass works, January 7th, 1747, of the extraordinary capacity of 105 imperial gallons.

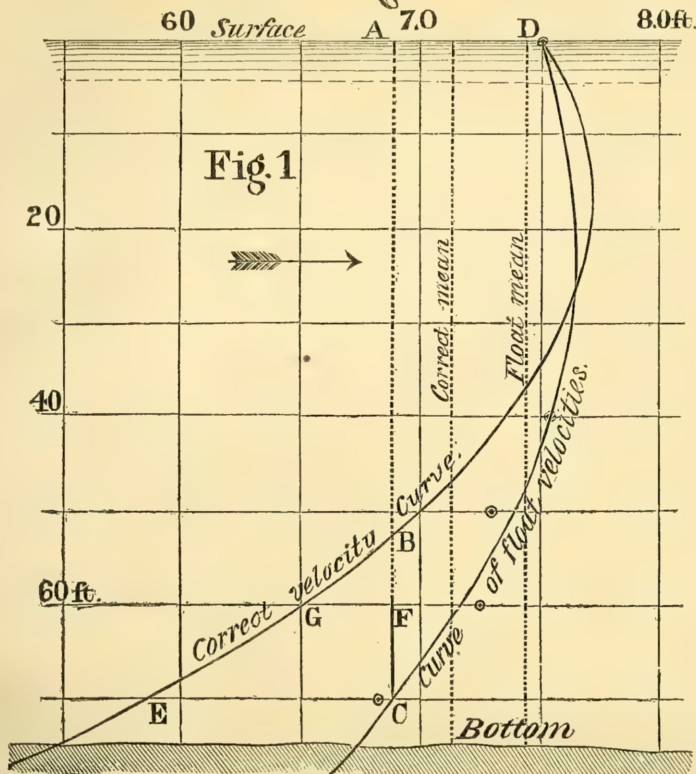
M. Violle considers that the emissive power of the sun at a given point on its surface will be the relatiou between the intensity of the radiation emitted at such point and the intensity of radiation which a body, having an emissive power equal to unity and carried to the temperature of the sun at the considered point, would possess. So that he defines the true temperature of the sun as the temperature which a body of the same apparent diameter as the sun should possess in order that this body having an emissive power equal to the average of the solar surface may emit, in the same period, the same quantity of heat as the sun. From experiments made at different altitudes, M. Violle determines the intensity of the solar radiation, as weakened by passage through the atmosphere, and finds, for the effective temperature of the sun, 2,822 deg. Fah. Investigations conducted with an actinometer by the dynamic method lead the investigator to conclude that steel, as it emerges from a Siemens-Martin furnace, has a temperature of 2,732 deg. Fah. If it be admitted that the average emissive power of the sun is sensibly equal to that of steel in a state of fusion, determined under like conditions, it appears that the mean true temperature of the solar surface is about 3,632 deg. Fah.

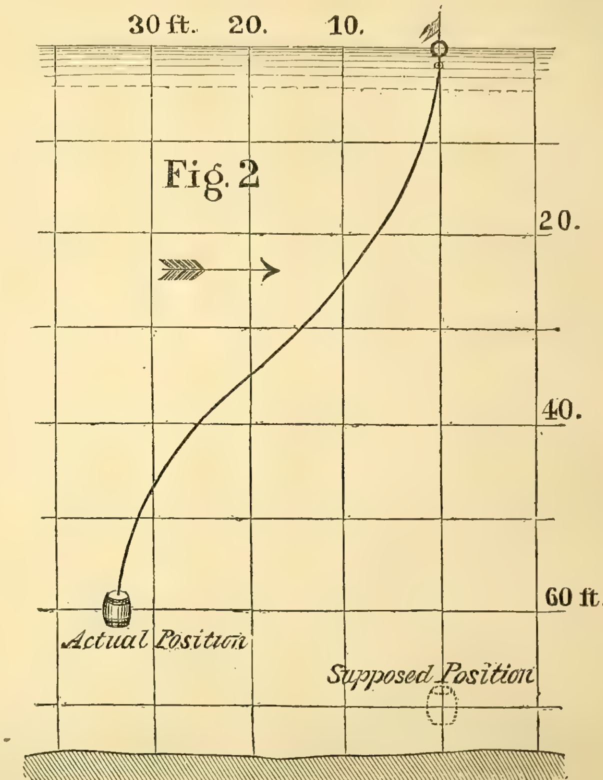
It appears from the following that iron water pipes have a distinct chemical value. Professor Medlock proved by analysis, several years ago, that iron by its action on nitrogenous organic matter produces nitrous acid, which Muspratt called "Nature's scavenger." The latter chemist found, as a general result, that, by allowing water to be in contact with a large surface of iron, in about forty-eight hours every trace of organic matter was either destroyed or rendered insoluble, in which state it could be purified effectually by filtration. Medlock found, on examining the water at Amsterdam, which smelt and tasted badly, that the sediment charred on ignition, and was almost consumed, showing that it consisted of organic matter. He also found that water, instead of taking iron from the service pipes, before entering them contained nearly half a grain of iron to the gallon; while in the water issuing from the pipes, there was only an unweighable trace.

Before entering the reservoir, the water holding iron in solution formed no deposits, while the water coming from the pipes, and freed from iron, gave organic sediment above mentioned. He then made analysis of water brought in contact with iron, and water not in contact, with the result that the water which had not touched iron contained 2.10 grains of organic matter, and 0.96 grain iron; the other gave only a slight trace of both, showing plainly that the organic matter in the water was either decomposed or thrown down by contact with iron, and this water, when filtered, was found to be clear, of good taste, with no smell, and free from organic matter. It is not stated in what shape the iron was held in solution, but it was probably in that of carbonate, the usual iron salt of springs.

Some weeks since a notice appeared in our pages of the use of a plain disc for cutting steel rails cold. Mr. T. L. Lewis, of Pittsburgh, states that for some years past M. Carnegie, Kloman & Co., of Pittsburgh, have been using a plain disc to cut large iron beams cold, and since its introdnction there that many other American mills have been using it for the same or similar purposes.—*The Engineer.*

Gauging of Rivers.





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ON RIVER GAUGING AND THE DOUBLE FLOAT.

By S. W. ROBINSON, Professor of Mechanical Engineering in the Illinois Industrial University.

Written for VAN NOSTRAND'S MAGAZINE.

THE *double float*, used so extensively by Messrs. Humphrey and Abbot,* in their investigations made between the years 1850 and 1860 on the Mississippi River, has proved in their hands to be a valuable means of finding current velocities. In the best form used by them, it consisted of a hollow cylinder (paint keg with bottom knocked out), ballasted so as to have a slight sinking tendency, for the lower part, and connected by a cord, which allowed it to sink to a certain depth, to a surface float only partly submerged, formed of a tin ellipsoid bearing upon a wire a small flag to assist in observing it.† The method adopted for using these floats was to put out several, one after another, from a boat stationed in the river and considerably above the points of observation. The time of passage of the floats between two parallel cross sections of the river was taken by the aid of two transit instruments, one stationed in each section; each float was observed across each section by both transits, so as to be able to locate the points of passage by triangulation. The sections were usually about 200 feet apart. These Mississippi gauging operations appear to be the first of importance in which the double float was used as the prevailing means for finding the velocity; though Mr. Chas. Ellet had previously used them to some extent on the same river.

Though the double float was suggested some 300 years ago, and employed to a limited extent, yet till quite recently it seems to have been used only for obtaining surface velocity,* the lower float being submerged only a few inches or perhaps feet. They were made of two balls of wax connected by a thread, and each properly ballasted; the object of their use having been explicitly to get surface velocity, but used in lieu of single floats at the surface for the purpose of reaching such a depth as to avoid influence of air currents upon the surface, and at the same time not exceeding that depth which would give the true surface velocity.

Subsurface, velocities, as such, were first observed by aid of Pitot's tube about in the year 1730. These experiments made known the true law of velocities, previously supposed to increase with depth.† This tube was also used to some extent and improved by Dubuat‡

* Gen. A. A. Humphrey's, Chief U. S. Engineers, and Gen. H. L. Abbot, Navy U. S. Engineers.

† See Report on the Physics and Hydraulics of the Mississippi River, by Humphrey and Abbot, p. 224.

* Encylopedia Britannica, 8 ed. vol. xii. p. 142, and Morins Hydralique, p. 114.

† Memoirs of the French Academy for 1732 and D'Aubuisson's Hydraulique, art. 151.

‡Bossut's Hydraulique, § 572, and D'Aubuisson's Hydraulique, art. 148.

and Mallet, and subsequently extensively used and greatly improved by Darcy.* In the form adopted by Darcy it is a valuable instrument, though, for a single observation, it only gives the velocity at the moment a certain stopcock is turned, which fixes the height of the water column until observed.

The early experiments with Pitot's tube on the Seine, not only overturned the theories previously advanced by Guglielmini, and supported by others, but made known the fact that the true mean velocity of a stream can only be obtained by measuring the velocity at various parts of the cross section.

Various instruments were subsequently devised for measuring the velocity of river currents.

Bossut† and also Dubuat‡ used a paddle or float wheel with floats parallel to the axis, and so placed when in action that the floats dip an inch or two into the surface of the stream. This was long since abandoned as the floats were too much influenced by the air.

Zendrini, Ximenes, Michelotti, Gerstner and Eytelwein,§ used the Hydrometric Pendulum, a ball suspended by a thread, in gauging the River Po. In use the ball was lowered into the current and the inclination of the thread noted.

Brünnings improved the Tachometer or pressure plate, and used it on the Rhine in Holland, and Ximenes on the Arno.‖ It was also used by Lorgna, Michelotti and Palette. Boileau describes a tachometer balanced by a spring instead of weights.

Racourt¶ used an instrument resembling a ship's log in important gauging operations on the Neva at St. Petersburg.

Woltmann's mill, or meter, however, is the instrument which has been most generally employed, and is believed by most hydraulic engineers to be superior to all other means ever used for determining the velocity of running water.**

* Morin's Hydraulique, p. 131.
† Bossut's Hydraulique, § 665.
‡ Morin's Hydraulique, p. 98, and D'Aubuisson's Hydraulique, art. 146.
§ Encyclopedia Britannica, vol. xii., p. 142, and Weisbach Mech. and Eng., p. 1,000.
‖ Brewster, D'Aubuisson, arts. 152 and 153, and Weisbach, Mech. and Eng., p. 1,001.
¶ Encyclopedia Britannica, vol. xii., p. 144.
** Enc. Brit., vol. xii., p. 144. Morin's Hydraul., p. 111. D'Aubuisson, art. 150.

M. Lapointe* adopted a Woltmann's meter wheel in his *gauging cylinder*, the registering apparatus being detached and carried outside by aid of level gearing. This arrangement was used in elaborate gaugings at the Powdermill *du Bouchet*, and also at the *Bassins de Chaellot.* This instrument is described at length and elaborately illustrated on plate 2, by Morin in his Hydraulique, and recommended for use. Woltmann's mill has been extensively used by Defountaine on the Rhine, including many points of observation, and by Baumgarten and Darcy.† Baumgarten recommends it very highly.‡

Krayenhoff, Buffon and Destrem used floats of the form of rods or poles so loaded that they rode nearly vertical in the stream, extending from the surface nearly to the bottom, aiming, by this means, to obtain the mean velocity at once of the longitudinal vertical section of the stream.§ This plan was perfected by J. B. Francis, of Lowell, Mass., who used loaded tin tubes two inches in diameter in straight and uniform flumes.‖ These experiments are among the most elaborate and trustworthy to be found recorded, and prove beyond a doubt the great value and precision of such floats in cases where the bed of the stream is sufficiently uniform. These floats give very nearly the mean velocity for the depth of the tube, without regard to the form of vertical curve of velocities. They would give it exactly if the resistance of a medium to solid bodies passing through it varied as the first power of the velocity. But varying as the second power, the true mean differs from the observed velocity of tube as pointed out by Mr. Francis. When the tube extends nearly to the bottom, calculation shows that for that depth the true mean is less than tube velocity by about five per cent.

Hirn used sheet floats in small canals which nearly filled the whole transverse section, and thus obtained, at once, the approximate mean velocity of the whole stream.¶

* Morin's Hydraul., pp. 99 and 100.
† Morin's Hydraul., p. 11, and D'Aubuisson, art. 152.
‡ Pants et Chaussées for 1847.
§ Humphrey's and Abbot's report on the Mississippi, p. 202.
‖ Lowell's Hydraulic Experiment, p. 172.
¶ Humphrey's and Abbot's Miss. report, p. 203.

Those gaugings which are conceded to be the most important of Europe were made with Woltmann's mill, the tachometer, and Racourt's ship's log. Of these instruments, the former receives the highest favor, and has been the most extensively used.

In this country, the double float and the Krayenhoff tube float, have been most used in gaugings of importance, though various current meters have been employed from time to time, and recently they have been rapidly gaining favor. A peculiar telegraphic meter was devised and used by Asst. D. F. Henry,* under Gen. W. F. Raynolds, Supt. U. S. Lake Survey, in extensive gaugings of the rivers of the Great Lakes undertaken in 1868–9. This meter is illustrated and described at length in the "Journal of the Franklin Institute," for May, 1869, p. 305. In these gaugings the double float, modeled after that used on the Mississippi, was first adopted, but afterwards abandoned as far inferior to the Henry meter.

This sketch of the various means which have been employed for measuring current velocities in river gaugings of importance, together with the names of those hydraulic engineers who adopted them in individual cases, and of those authors who described and used them, has been given that we may form an opinion of the relative merits of the different instruments based on the estimate placed upon them by men of eminence. It is clearly indicated that a current meter or *moulinet* of some form stands in most universal favor, the Woltmann's mill being one of the best.

It is evident that those qualities which should be possessed by a current measurer are: 1st, accuracy and constancy in indications; 2d, that it give the mean velocity for the time during which a single observation is taken; and 3d, that it be convenient and reliable. That these qualities are found possessed in the highest degree in a well constructed current meter is made clearer by noticing a few points of peculiarity in the different instruments, and of difficulties in the way of their use. In all streams there is more or less of eddying, and of unaccountable meandering local currents continually shifting the water in lateral directions. These are liable to take effect upon the instrument causing it to record a greater velocity than that which it evidently should, viz.: the horizontal component. Pitot's tube in its best form, as for instance it was left by Darcy gives, for one observation, the component parallel to the tube at its open end at the instant the column is fixed. The fluctuations of the column, however, are reduced considerably by reducing the bore of the tube at some part to a small calibre, by which means the height of column is made to represent approximately the mean height for a time more or less extended, though at best the interval will be short. This requires numerous raisings and lowerings of the instrument. In the tachometer we have difficulty with the variation of the pressure against the plate. The ship's log is free from this, but it is liable to be led about in various directions by the transverse currents, giving an erroneous result. The double floats are likely to be subject each to such lateral currents and one float never found above the other; this inclines the connecting cord decreasing the depth. The Woltmann's mill, if directed by a vane, will head in various directions and not give the up-and-down stream component of velocity. In the illustrations, however, this meter is represented as attached rigidly to a pole or rod, which, when rightly directed, will give the desired component. The illustration of Henry's meter represents it as directed by a vane. The same is true of Baumearten's Velocimeter. These should be rigidly held in a position directed up stream, unless it can be shown that the lateral movements of the water have no appreciable effect to turn it out of its true course when directed by a vane.

The objections above noticed are seen to be unavoidable in every case, except the current meter, in its different forms. As the current meter is one of the most convenient instruments for use, there seems to be sufficient cause for the prevailing preference for its use.

In selecting a current meter, the best form, of course, should be adopted. It must necessarily have some form of register. This is usually attached to the instrument and submerged with it, and generally, in fact, regarded as part of the

* Now Chief Engineer of the Detroit Water Works.

instrument. But we find an exception to this in the Henry meter. The meter wheel, in this, has simply to break an electric circuit at each revolution, the same being recorded by an electric register at the surface. This separation of the wheel-work and relief of the meter wheel from the load of driving them is very advantageous, for the resistance of the wheel-work in water of variable degrees of grittiness must be different at different times, causing irregular indications. Also the register being at the surface, it is not necessary to raise the meter at each observation. From these facts it appears that the Henry telegraphic meter or moulinet possesses advantages which render it superior to all other means yet tried for measuring the velocity of running water in large rivers.

It is much to be regretted that the gauging operations on the lake rivers were prematurely stopped, preventing the more thoroughly testing of this instrument. Enough was done, however, to indicate its superiority over double floats, with which it was put in experimental comparison, and which finally led to the abandonment of the floats and the adoption of the meter.

Careful comparative observations of the floats and meter indicated almost perfect agreement at the surface, but below this the floats gave too high velocities, increasing with depth. These discrepancies led to the discovery of errors due to floats which Mr. Henry pointed out in substance as follows*: First, the upper float drags the lower increasing its velocity. Second, the pressure of current against the connecting cord increases the velocity of the lower float; and Third, these effects incline the cord down stream and raise the lower float. The comparisons indicate that a correction should be applied to gaugings made with double floats by deducting about six per cent.

The necessity of a float correction becoming evident, the writer was requested to make a mathematical investigation of the matter, the results of which were forwarded to Mr. Henry some time after and published in his pamphlet on the flow of water. Though the analysis is somewhat complex, the correction found confirms the result obtained by experimental comparison of the float and meter.

In the analytical problem a vertical curve of velocities was required in order to determine the pressure of current against the connecting cord. This was assumed elliptical and agreeing with the observed float velocities. This assumption was perceived to be illogical, because it rendered implicit the curve which it sought to correct. But this was done because the true curve was unknown, the first result being regarded only as an approximation, giving a new curve which could be again used for a second approximation, &c.

The table below, taken from Mr. Henry's pamphlet, contains the first corrections, and the ordinates of the resulting curve, found by aid of the formulas, for an example of double float measurements taken from the report of Humphrey's and Abbot, p. 230. The observations were taken on the Mississippi River at Carrollton, La., in 1851.

COMPUTED CORRECTIONS FOR FLOAT OBSERVATIONS.

Depth of float, ft.	Observed velocity.	Computed velocity.	Difference
0	4.230	4.230	0.000
18	4.298	4.298	0.000
36	4.346	4.346	0.000
54	4.274	4.250	0.024
72	4.158	4.015	0.143
90	4.053	3.785	0.268
102	3.948	3.275	0.673
110	Bottom.	2.670	

These figures show quite large corrections for the greater depths, and for the mean velocity a correction of about 3.8 per cent. This correction falls somewhat short of that obtained by Mr. Henry in his direct comparison of the float and meter, a result which may be partly attributed to the fact that the second or third corrections were not computed.

Since the publication of Mr. Henry's pamphlet, the problem has been thoroughly reviewed with a view to simplifying the formulas, and of obtaining more complete corrections. Rigorous methods led to complex formulas, for

* Pamphlet on the Flow of Water, by D. F. Henry, p. 16, and Jour. Fr. Inst. for 1871.

which reason approximate methods have, in part, been adopted, not, however, without comparing in each case with the exact formulas, the results obtained by computation.

As these formulas are of great value in discussing the double float system, and lead to a knowledge of the best form of double float for practical use, they will be given here, together with an example to show their application in computing corrections.

The nature of the problem is as follows: The float combination, consisting of the upper and lower floats and connecting cord, is supposed to be observed when moving down stream with a common velocity. The weight of the floats and cord are supposed to be known, and also the approximate form of the vertical curve of velocities. Required the velocity of the water at the lower float.

Let v_0 = velocity of water at surface of stream.

v_c = velocity of current at any depth y.

v_1 = common velocity of float combination.

v_2 = velocity of water at lower float.

v_m = maximum velocity of water in the vertical section.

W = weight of lower float when immersed, and also assumed equal to the tension of the connecting cord at any point.

a_1 = area of upper float presented to current.

a_2 = area of lower float presented to current.

r = radius of connecting cord.

c_1 = coefficient found by experiment giving pressure of current upon units section of upper float at units velocity.

c_2 = similar coefficient for lower float.

c = similar coefficient for connecting cord.

x and y = coördinates of curve of connecting cord, origin at upper float.

d = depth of stream in the longitudinal section considered.

For a cylinder* $c = .75$, and resistance $= .75\, a v^2$.

For a sphere $c = .50$, and resistance $= .50\, a v^2$.

The velocity of the water past the upper float is $v_0 - v_1$, and hence the pressure of the water upon it is

$$P = A_1\, C_1\, (v_0 - v_1)^2 \text{ lbs.} \qquad (1)$$

For the lower float the velocity is $v_1 - v_2$, and the pressure upon it is

$$P = A_2\, C_2\, (v_1 - v_2)^2 \text{ lbs.} \qquad (2)$$

Dividing the cord into elementary lengths dy, an elementary area will be $2\, r\, dy$, and hence an elementary pressure against it is

$$P = C\, 2\, r\, dy\, (v_c - v_1)^2 \qquad (3)$$

And the total pressure upon the cord from the surface to the depth y is

$$\Sigma P = 2\, c\, r \int_0^y (v_c - v\,)^2\, dy \qquad (4)$$

It is to be observed that the difference $v_c - v_1$ changes its sign between the surface and lower float, while the square does not; so that the integral between these limits would express the sum of the upstream and downstream pressures instead of difference, which is required. This expression is of the same form as that for the *moment of inertae*, for which the sum is reqired instead of difference, and hence extreme limits admissible. For the present case our limits would be the surface and depth where $v_c = v_1$, and then the latter limit and depth of lower float. The difference of the numerical values of these two quantities is then to be taken. This leads to such complicated expressions that they have only been used to check the approximate formulas, and insure their trustworthiness.

The velocity $(v_c - v_1)$ of the water past the cord at various depths y, sometimes positive and sometimes negative, is the distance from an axis A B to the true curve of velocities D B E, Fig. 1. If now the mean ordinate to this curve be found, it may be introduced into a formula, to give an approximate value of the pressure of current against the cord. Let this be represented by $(v_n - v_1)$.

* Rankine's Applied Mechanics, p. 599, and Bennett's Morin's Mechanics, p. 375.

Then

$$\Sigma\,P=2\,cr\,(v_n-v_1)^2 y \text{ nearly.} \quad (5)$$

To determine this mean ordinate we have

$$(v_n-v_1)y=\int_0^y (v_0-v_1)dy. \quad (6)$$

To find an expresssion for the equation of the curve of cord, we may take moments about any point of it, of the forces acting upon the combination above that point: thus

$$Wx=(y-\bar{y})\,\Sigma\,P+a_1c_1\,(v_0-v_1)^2y. \quad (7)$$

In which $\bar{y}$ is the depth of the center of pressure upon that part of cord considered. To get a simple expression for others, it is assumed to be at the center of gravity of the area below A D to the depth considered. Hence

$$y\,(v_n-v_1)\,\bar{y}=\int_0^y (v_0-v_1)y\,dy \quad (8)$$

To find the true velocity of water v_2 at the lower float, we have by equating the horizontal forces acting upon the float combination,

$$a_2\,c_2\,(v_1-v_2)^2=a_1\,c_1\,(v_0-v_1)^2+\Sigma\,P. \quad (9)$$

Assuming that the vertical curve of velocities is a parabola with its axis horizontal and some depth below the surface of stream, as done by Humphrey and Abbot and others, we have

$$(y-nd)^2=2\,P\,(v_m-v_0) \quad (10)$$

for its equation, the origin being taken at the surface of the stream, and at a distance v_m from the vertex. The principal axis of the parabola is at a depth nd, and $2\,P$ is the parameter of the parabola. The curve might be assumed elliptical, or of any other form.

Combining (10) with (5), (6), (8) and (9), we get

$$(v_n-v_1)y=\int_0^y\left((v_m-v_1)-\frac{(y-nd)^2}{2\,P}\right)dy$$

$$=\left\{(v_m-v_1)y-\frac{(y-nd)^3}{6\,P}-\frac{n^3d^3}{6\,P}\right\}$$

$$\Sigma\,P=2\,cr\left\{(v_m-v_1)-\frac{(y-nd)^3}{6\,Py}-\frac{n^3d^3}{6\,Py}\right\}^2 \quad (11)$$

$$\bar{y}=\frac{y}{2}\left\{\frac{(v_m-v_1)-\frac{1}{P}\left(\frac{y}{2}-\frac{2\,nd}{3}\right)^2-\frac{n^2d^2}{18\,P}}{(v_m-v_1)-\frac{(y-nd)^3}{6\,Py}-\frac{n^3d^3}{6\,Py}}\right\} \quad (12)$$

$$v_1-v_2=\left\{\frac{a_1c_1}{a_2c_2}(v_0-v_1)+\frac{\Sigma\,P}{a_2\,c_2}\right\}^{\frac{1}{2}} \quad (13)$$

$$x=\frac{y-\bar{y}}{W}\,\Sigma\,P+\frac{a_1\,c_1}{W}\,(v_0-v_1)^2y \quad (14)$$

It is evident that in all these formulas which involve the action of the current upon the cord or connecting line, such values of nd and $2\,P$ should be used as belong to the true curve of velocities; and not such as are found from the curve of observed float velocities. This effect may be secured in two ways; first, by a series of approximating curves as above mentioned; or second, by assuming a guess curve or parabola, and proving it by a computation, using nd and $2\,P$ as belonging to it. The latter is in effect the same as the former—we guess at the first approximation instead of calculating it.

In proving the guess curve two computations must be made, one to determine the amount the lower float is raised by the inclination of cord, and another for the difference of velocity of the lower float and of the current in which that float is dragged. The first is represented in Fig. 1 by C F and the second by F G. When these are obtained, they are to be plotted as shown in Fig. 1, on the same diagram with the parabolas. Starting from C, if G pulls on the guess curve, that curve is the one sought, unless its figure be changed by similar computations and plottings for other points.

The guess curve is assumed, for convenience sake, to be a parabola obtained by multiplying all the vertical ordinates, y, of the primitive parabola by a certain constant fraction m. If, for instance, A C$=70$ and A B$=50$, $m=\frac{50}{70}$. By so doing it is to be observed that B is the point where the velocity of the stream is the same as the observed velocity of the floats for the particular cord length, or supposed depth A C. This amounts to estimating the position of B and finding m. Then our guess parabola has the equation

$$(y - mnd)^2 = M^2\, 2\, P\, (v_m - v_c)$$

which can be easily shown. If this is done, then these values of mnd, and $m^2\, 2\, P$ are to be used for nd and 2P in equations (11) and (12.)

If the parabola thus found is believed to represent, with sufficient accuracy, the real curve of velocities, its mean ordinate, for a depth d, is to be compared with the mean ordinate of the primitive parabola for a like depth, to obtain the correction, per centum, for the float observations in the vertical longitudinal section of the stream considered. It will, however, be better to compute several corrections for different heights in the vertical, in the manner shown in Fig. 1, after which a curve, parabolic, elliptical, or otherwise, should be found which best agrees with the points, and it adopted for the true curve of velocities.

The problem is thus solved as far as proposed in this article. The formulas are approximate, but differ so very slightly in their results from the thoroughly rigorous formulas first worked out, as proved by very laborious computions, that the discussions and examples following will be regarded as consequences of the rigorous formulas themselves.

The formulas furnish the following hints which should be observed in conducting float observations:

1st—connecting cord.

The value of (11) increases directly as r or radius of cord. Hence the line connecting the floats should be reduced to the least possible value to make the pressure upon the cord a minimum. For instance, to reduce the cord from 0.2 of an inch to a wire 0.01 inch in diameter reduces this pressure twentyfold. As ΣP in (13) is the principal part of that equation, we have the velocity correction varying nearly in the direct ratio of the square root of r. And similarly x varies nearly as the first power, $q\ r$. Hence, in every sense it is essential to reduce the diameter of the connecting line to the very minimum. It should, therefore, be a wire, which, for the usual dimensions of the floats, may safely be a hundredth of an inch or less.

2d—ballasting.

In (14), W is the weight of the lower float when immersed, or tension of the cord, which shows that to reduce x, the falling back of the lower float, W, should be considerable. If x can be so decreased as to make the rising of the lower float, depending upon the inclination of the cord or line, inconsiderable, three-fourths of the labor of computing corrections would be avoided. This indicates that W should be given as large a value as practicable without unduly increasing the volume of the upper part to support it. Though the latter increases the velocity correction as indicated by (13), still the tenu involving a is usually small compared with the other; and the value of a, whether great or small, makes but little difference with the labor of computing corrections. As W enters no other formula, it is evidently not good policy to make it excessively small. The example given further on will aid in deciding this point.

3d—form of upper float.

It is evident that its form should be that of least resistance, which is a sphere or ellipsoid.

Suppose W to be wholly resisted by the buoyancy of the upper float, the latter without weight, and a spheroid with shortest axis vertical. Let the half depth = h, and the horizontal radius = b, then

$$W = \tfrac{1}{2}.\tfrac{4}{3}.\ \pi\, b^2\, h\, \delta,$$

and

$$a_1 = \tfrac{1}{2}\, \pi\, b\, h = \frac{3\, W}{b\, \delta}$$

in which δ is the density of the water, the upper float always being supposed to be half immersed.

Now regarding W as constant, we see that a varies inversely as b the diameter of the float. Hence the upper float should be a large and flat ellipsoid lying on the surface of the water, that a may thereby be reduced to a minimum.

4th—form of lower float.

As a_2 and c_2 appear only in the denominator of (13), both should be made as large as practicable. A hollow cylinder, like a cask with both top and bottom

knocked out and held upright, would evidently be a good form.

These hints all agree with statements of Gen. H. L. Abbot, in an article in the "Journal of the Franklin Institute,"* as far as made, except he says the upper float should be *minute.* This would require a *very small* value for W, and hence give great danger of the rising of the lower float to an unknown depth, particularly in deep rivers. *Small* would be sufficiently superlative.

AN EXAMPLE.

The following example has been completely worked out to show the application of the formulas in correcting double float velocity measurements; and not only this, but to make clear the necessity either of correcting the float observations or of following the hints brought out by the discussion of the above formulas.

The example selected is of double float observations taken at Vicksburg, Miss., May 13th and Aug. 7th, 1858, on the Mississippi River in a depth of 75 ft., and is found reported in the second table in page 246 of the "Report on the Physics and Hydraulics of the Mississippi River," by Humphrey and Abbot. This example is chosen because the velocity of the river at this point is quite large, for which it is supposed the floats would be most disturbed, and not because the number observations at each depth is few. The sequel, however, shows that the disturbing influence of swift currents is proportionally about the same as for less velocities. The data for this example as appearing on page 246 are given in the following table, together with the ordinates of the parabola which are found to agree best with the float observations.

"SUB-SURFACE VELOCITY OBSERVATIONS UPON THE MISSISSIPPI AT ITS HIGHEST STAGE, THE DEPTH BEING ABOUT 75 FEET."

Depth, ft.	Velocity observed.	Ordinates of Parabola	Difference.
0	7.50	7.50	.000
40	7.54	7.533	+.007
50	7.29	7.380	−.110
60	7.33	7.162	+.168
70	6.82	6.880	−.060

*"Journal Franklin Institute" for May, 1873, p. 308.

Equation (10) gives the ordinates in the third column by making

$$nd=21.283,\ 2\,\mathrm{P}=3097.4,\ v_m=7.646.$$

A guess parabola is assumed which starts from the same point at the surface, has the same maximum ordinate v_m, and for which, for any given value of v_c, the value of y, is only $\frac{5}{7}$ that of the above primitive parabola. Hence, for this guess parabola

$$m\,nd=15.2,\ m^2\ 2\,\mathrm{P}=1580.\quad v_m=7.646,$$

which are to be used for nd and 2 P in the general equations (11) to (14) in proving the guess parabola. The vertical and horizontal corrections C F and and F G, Fig. 1, may be found for any point of supposed depth, say 70 ft. By aid of (14) the values of x, for given depths y, are computed; which are the co-ordinates of the curve the connecting cord assumes when the float combination has settled into equilibrium in the stream. These are given in the table below.

In these computations definite values for W, c, r, a_1, c_1, a_2, and c_2 are required. On page 224 of the Mississippi Report $2\,r=$ somewhat less than 0.2 inch, say $=.18$ inch$=.015$ ft.: $a_1=.022$ ft. by assuming the float to be the ellipsoid $5\frac{1}{2}$ inches in diameter by $1\frac{1}{2}$ inches deep half immersed, instead of the half inch pine board $5\frac{1}{2}$ inches square, both of which were used in 1858, but which, in this example, is not stated: $a_2=\frac{2}{3}$ ft., it being a keg 8×12 inches. But W is not given in the report, and hence must be estimated. The weight of the tin of ordinary thickness; solder; flag and wire for supporting it; say .25 lb. The semi-ellipsoid would displace .42 lb. of water. Difference$=W=.17$ lb. The values of c are given above. Hence

$$\frac{a_1\,c_1}{a_2\,c_2}=.022,\ 2\,cr=.0112,\quad \frac{a_1\,c_1}{W}=.0815.$$

This curve is plotted to scale in Fig. 2. It is observed to be somewhat "S-shaped," the reversing of the curvature being due to the fact that the lower portion of the cord is itself dragged along more rapidly than the water moves. The lower float is observed to be very far from the position supposed.

TABLE OF CO-ORDINATES OF THE CURVE THE CONNECTING CORD ASSUMES IN THE CURRENT.

Depths in ft. y	Values of x ft.
0	0
10	1.55
20	6.90
30	14.72
40	26.26
50	31.92
60	34.03

Now laying off 70 ft. on the curve, we find the float to be situated at Fig. 1, and at an actual depth of almost exactly 60 feet only, including an excessive lifting of the lower float.

This depth, 60 feet, is now to be used for the actual depth of lower float, y, in (11) and (13), for computing the velocity correction. This is found to be

$$v_1-v_2=0.516 \text{ ft.}$$

Laying this off from F, Fig. 1, brings us exactly to the guess curve; which shows that this curve was correctly assumed, and hence we have one point in the real, or corrected curve of velocities.

The correction found in a similar manner for a cord of 50 ft. length gives the horizontal displacement of float, $x,=2.51$, which is too small to decrease the depth appreciably. Then

$$v_1-v_2=0.187 \text{ ft.}$$

Similarly for a depth of 30 ft.

$$v_1-v_2=0.020.$$

These when plotted ought to give points on the guess parabola, but do not exactly. Plotting them, and working out a parabola which best fits them all, we find

$$nd=17.32 \quad 2\,\mathrm{P}=1500. \quad v_m=7.7.$$

Taking this and proceeding to a second approximation, we get no appreciable change in the position of the curve of velocities. The parabola is the curve which fits them best, confirming in this case the parabolic law of Humphrey and Abbot.

The equation of the correct velocity curve, in which v_c represents the velocity of current for the depth y, is therefore

$$(y-17.32)^2=1500\ (7.7-v_c)$$

The curve, agreeing best with the float observations from which Messrs. Humphrey and Abbot took their mean, is

$$(y-21.283)^2=3097.4\ (7.646-v_c)$$

Hence the actual mean velocity of the river at Vicksburg, in the vertical considered, is the mean ordinate of the above corrected parabola for a depth $d=75$ feet, which, found by an equation like that just preceding (11), is

Correct mean 7.148 ft. per sec.

Mean according to the floats, and as the Mississippi Report would have it, for the vertical considered,

Float mean 7.458,

greater than the true mean by over 4.3 per cent.

This correction does not differ very far, per centum, from that found from the example quoted from Mr. Henry's pamphlet.

I wish to call attention, before passing to the resemblance between the above computed corrections for the Vicksburg observations, and those obtained by Mr. Henry in his experiments on the St. Clair River, both of which are presented in the following : (*See table next page.*)

The table explains itself. Let us compare the columns of differences. These, we observe, are negative down as far as to point of maximum velocity, below which they are positive in both cases, and increase with depth. Though the differences found by meter are greater proportionally at mid-depths,—at points near the bottom they are nearly alike. But by more careful inspection it is seen that the apparent dissimilarity at mid-depth is more seeming than real. The point of maximum velocity is at a greater proportionate depth in the Mississippi velocities than in the St. Clair. At proportionate depths reckoned from this, there is an almost exact similarity in the *pro rata* value of the differences, which fully explains the apparent anomaly, and really exhibits a wonderful conformity of the results. This would indicate that the correction, *per centum*, would be

TABLE OF FLOAT VELOCITIES COMPARED WITH ACTUAL VELOCITIES.

Observations at Vicksburg, Corrects by Calculation.				Observations in St. Clair River, Corrected by Telegraphic Meter.			
Depth feet.	Ordinates of Parabola agreeing with Float Observations	Ordinates of Parabola agreeing with Computed Velocities.	Difference.	Depth feet.	Velocity by Floats.	Velocity by Meter.	Difference.
0	7.500	7.500	.000	0	3.619	3.655	−.036
10	7.605	7.664	−.059	5	3.759	3.782	−.024
20	7.645	7.695	−.050	10	3.703	3.674	+.029
30	7.621	7.593	+.028	15	3.590	3.516	+.074
40	7.533	7.357	+.176	20	3.598	3.405	+.193
50	7.380	6.988	+.392	25	3.637	3.441	+.196
60	7.162	6.486	+.675	35	3.556	3.166	+.390
70	6.880	5.849	+1.031	45	3.542	2.985	+.577
75	Bottom.			50	Bottom.		

greatest in those cases where the maximum velocity of stream is nearest to the surface. In the corrections to the Carrollton gauging, given above, the maximum velocity is at proportionally the same depth as in those of Vicksburg, and we find the correction about the same, *per centum*, regardless of the great difference in velocity of stream.

These examples indicate that in streams where the maximum velocity is at about a fourth of the depth, as in the Mississippi observations, the correction is about 4 per cent.; and where the maximum velocity is at a seventh of the depth, as in the St. Clair experiments, the correction is about 6 per cent.; that is to say, the denominator of the fraction expressing the depth of maximum velocity, is very nearly the *per centum* rate of correction for the gauging.

This rule, if more fully verified by more numerous examples, would only apply in cases where the double float used is patterned after those used on the Mississippi by Humphrey & Abbot. If the conclusions or hints above pointed out as consequences of the general formulas be carefully observed in designing the float, the corrections may be reduced to such inconsiderable quantities as to be overlooked. For instance, if a correction of 4 per cent. arises principally from a cord 0, 2 inches in diameter, a cord a twentieth of that size would require a correction of less than a fourth of the former, or less than one per cent. This is a consequence of (13) and (11), which show that the velocity correction varies nearly as the square root of the diameter of the connecting line.

A wire filament a hundredth of an inch in diameter, connecting the floats, would present to the current, for a depth of 90 feet, an aggregate area of three times that of the upper float of the size and form of the tin ellipsoid used in 1858. This shows the importance of giving attention to reducing the resistance of the connecting line, rather than that of the surface float, particularly for great depths, and also the hopelessness of endeavor of rendering the action of the current upon the line insignificant as compared with the upper float resistance.

Though the dragging action of the upper float upon the lower appears to have been considered while the Mississippi observations were going on, as indicated by the fact that observations were made to ascertain the effect of the wind upon the upper float to drive the combination about; and as also evinced by the reduction of the area presented by the upper float from 12 square inches to 3 square inches between the observations of 1851 and 1858; yet the effect of the connecting cord, nearly a quarter of an inch in diameter, appears to have been entirely ignored.

A cord 0, 2 of an inch in diameter, stretched through a depth of 90 feet,

would present to the current an area of 216 square inches. The largest upper float used presented only 12 square inches, an insignificant quantity comparatively. The largest lower float used was 10×15 inches, presenting an area of 150 square inches, giving a total of both floats of 162 square inches; an area only three-fourths of that of the connecting cord. It is therefore plain that for these depths the cord, itself, must have become the prevailing float instead of the float proper, the observations going on more after the manner of the Krayenhoff pole float type, than according to the double float system, giving, in reality, no idea whatever of the actual velocity of the water at the depth where the lower float was supposed to be. It is difficult to discover how the connecting cord could have escaped the consideration of the Mississippi observers, when the upper float received so much attention, a matter of comparatively no consequence whatever.

Since the appearance of the float and meter comparisons, it has been suggested by several that the connecting line be reduced to a fine wire; and prominent among them is Gen H. L. Abbot* himself, who is supposed to be in a measure responsible for the dimensions of the float combination used on the Mississippi River. As regards the suggestion by Gen. Abbot, coming from a man of his good judgment and experience in the line of river hydraulics, it may be considered as favorably supporting the points made above; and in the light of the above showing, as equivalent to an admission that double floats, modeled after those used on the Mississippi, cannot give the exact velocity.

* Jour. Fr. Inst. for May, 1873, p. 308.

AIR AND VENTILATION.

By W. N. Hartley, Esq., F. C. S.

From the "Journal of the Society of Arts."

In the treatment of this subject, I shall be compelled to omit any consideration of the first half of the title, and confine myself to ventilation simply, or I would rather say, to the pollution of air, and rendering of air fit for breathing. When we analyze very carefully the atmosphere we find it consists of one volume of oxygen diluted with four volumes of nitrogen, the oxygen being an active gas, diluted with an inactive gas. Therefore, generally speaking, air has the properties of oxygen somewhat enfeebled. Besides this, we have in air a small quantity of ammonia and a small quantity of carbonic acid; that is the common name, but the scientific name is carbonic anhydride, and it is also called carbon di-oxyde. Now the quantity of carbonic acid, as I shall call it, is only very small, but nevertheless it varies very widely within very small limits. The properties of this gas form the first part of my subject. To begin then with the properties of carbonic acid, there are two which are especially remarkable—one is the very great weight of the gas, and the other is the property it has of extinguishing flame. With regard to the sources of the gas. Before I show its properties, I will show the sources of this gas. First of all, there is combustion; and besides the sources of the gas I shall have to refer to the means by which we detect it when it exists in any considerable quantity in the air, for which purpose lime-water is a very convenient test. To show that carbonic acid is produced by combustion, I place some clear lime-water in a jar in which a gas jet has been burnt, and you see the lime-water becomes turbid in a very short space of time from the separation of the insoluble carbonate of lime. The next source is respiration. This may be easily shown in the same way by the aid of lime-water. Here is an apparatus through which I can draw the air necessary for my respiration. First of all, the air passes through lime-water, and by so passing through lime-water it will show you if there is any considerable amount

of carbonic acid in the air; secondly, the air from the lungs passes through lime-water again, and that will show whether there is any excess of carbonic acid in the air of the lungs over that in the ordinary air. You will see that in one of these bottles, the one through which the air passed, the lime-water is clear, while that through which my breath passed is turbid, showing that the breath is a source of carbonic acid. Then I have again to show you the properties of this gas when we take care to have it undiluted with air, and in order to get it undiluted with air as much as possible we prepare it from marble, and any strong acid, such as hydro-chloric acid or sulphuric acid. This apparatus is now making carbonic acid, and here is a vessel into which this carbonic acid is evolved. The gas there you see is colorless at any rate. Here is another vessel which also supplies me with a certain amount of carbonic acid, and with this vessel I propose to show you the power that carbonic acid has of extinguishing flame. Both these experiments also explain to you that carbonic acid is a heavy gas; in other words, if the carbonic acid were lighter than air, as there is an opening in the top of this vessel, it would readily escape from such a large jar as this, but as it is a heavy gas, you may remove the top of the vessel, and the carbonic acid will remain in it for a short time. To show that there is carbonic acid in this jar, I will put a lighted taper in it. You see that it is extinguished. But to show it on a large scale, I will take a torch of tow and set fire to it; you see it is at once extinguished in this jar of gas. To show you that it is a heavy gas I will inflate this small balloon with air, and put it into this glass, and we shall see whether the gas is sufficiently heavy to float the balloon. You see it only just floats, half way up the glass; but if I blow a soap bubble it will float on the top of the gas. At any rate, you see these two effects of carbonic acid—first, that it extinguishes flames; and secondly, that it is a very heavy gas. I have to bring before your notice the fact that in the outside air the carbonic acid is so mixed up with the oxygen and nitrogen that the air practically over all parts of the world has the same composition; and, although it has not exactly the same composition, yet the variations are within very small limits. Nevertheless, the air of the mountains on the sea shore of Scotland varies from the air in the streets of London, and this variation, which is occasionally small, you will see is of considerable importance by the tables on the wall. These tables, which are taken from the analysis of Dr. Angus Smith, show not only the variation in the air of towns from the air of the country, but also show the variations between the air of one street and that of another. Here is the air from various places in Scotland on the hills. If this table be read with the first number as a whole number, then we must count it as volumes in 10,000 volumes of air; and that will give us 3.2 volumes in 10,000 of air. At the bottom of the hills it is 3.41 in 10,000. Then we come to London; in the parks and open places the air contains 3.01 volumes of carbonic acid in 10,000; on the Thames 3.43 in 10,000; in the streets 3.8—that was in April, 1864. Later on, in April, 1869, we get the carbonic acid in the streets as 4.39. In Manchester during fogs, 6.79, which is a considerable variation from Scotland on the hills. Then I come to some large numbers, which I will not allude to just now. In this table we have the analysis of air in duplicate, so as to ensure the accuracy of the analysis. In the north, north-east and north-western districts, Dalston, Hoxton, Hackney, St. John's Wood and Belsize Park, we have a series of analyses made, and the average of these, with that of Belsize Park omitted, gives us 4.445 in 10,000. In the west and west-central districts it amounts to 4.115; that is, Woburn Square, Tavistock Square, Regent Street, Oxford Street, Hyde Park and Sloane Street. In the east and east-central it is 4.745 in 10,000. In looking at these tables it must strike anyone that in the part of the town where it is open, consisting of wide streets and squares, with houses thinly inhabited, that is to say, large houses and no factories, the air is considerably better than in the east of London, where there are crowded neighborhoods, such as Bethnal Green, and where there are narrow streets and manufactories of different kinds. This, then, shows that we have considerable variations in the air even in one town, although that town is

certainly the largest we can take for the illustration.

Now, as air is vitiated by carbonic acid produced by combustion and by respiration, when a number of people are gathered together in a room, what becomes of the carbonic acid produced by respiration and combustion? Fortunately, the heavy gas is so acted upon that it ceases to be heavy, and rises to the ceiling, and so we have a natural means of ventilation. This I propose to show you very shortly. I have here arranged two little jars, which, I think, will show the same thing on a somewhat smaller scale. They both contain carbonic acid. That I will see first, by putting in a taper, when they both extinguish it. I will put them under precisely the same conditions, except that I will warm the gas in one jar, and to do that I will put in a little flask containing water, the water in one being hot and in the other cold. After a few minutes I will test them again with the taper, and see whether they are in the same state. While that is in operation, I will show you what becomes of the gas and the vapor produced by an ordinary fire or burning gas. That is easily done by confining the gas produced by the combustion of a large gas burner in an air balloon, and the balloon will soon be inflated and rise to the ceiling, showing the course the burnt gas would take. It is evident that the gas rises to the ceiling. We have there one natural kind of ventilation. Now I will show you with the tapers whether these two jars of carbonic acid are in the same state as they were at first. The taper is put out in one, but in the other it still burns as brightly as it would in the open air; the carbonic gas warmed by the flask of hot water has made its escape.

The next fact I want to show is that if air has once been drawn into the lungs and ejected, it is useless for either respiration or combustion. I can show it is useless for combustion, and you must take my word for it that it is not fit to breathe. If I extract the air from this jar and then return it from my lungs into the jar again I shall be able to test it with the taper, and to see whether it will furnish the taper with sufficient oxygen to cause it to burn. You see the taper is extinguished, all the oxygen of the air has not been taken out, as I will show you directly. The amount of carbonic acid in the expired breath is about 5 per cent. I have a little phosphorus here in a spoon, and as phosphorus is much more combustible than gas or a taper which will burn with less oxygen, therefore, if there is still any oxygen here I shall be able to burn it in the jar —it does not burn quite so brightly as it did in the open air, but it still burns.

The next experiment is to show the deterioration of the air by means of combustion; in the same way if the taper be burnt in the air, and be allowed to burn so as to consume so much oxygen that there is none left, it goes out. But by a little arrangement I can show you that there is still oxygen in the air, that it does not consume it all. There is the taper burning in the jar, and I will close the bottom, and make it air-tight by a drop of water. This wire passing into the jar is getting hot, so that I may be able to touch a piece of phosphorus in the centre. As soon as the taper goes out, I shall by that means be able to kindle the phosphorus, and show that all the oxygen in the jar has not been used up. Now, you see, the taper has gone out, but still that there is oxygen there is shown by the combustion of the phosphorus. The first effect, then, of respiration and combustion on the air is to render it unfit for respiration again, and unfit for combustion. We already see that the carbonic acid produced by combustion and also by respiration to a certain extent being heated, rises to the upper part of a building; and there are other means yet, besides this lightening of the heavy carbonic acid gas which causes fresh air to be introduced into a house. Some experiments made by Fedderson, of Leipsic, show that when there are two atmospheres in two different states, one hot and the other cold, there is between these a porous medium for the passage of the gas from the cold to the hot side. So that it comes to this, if we take a tube and put a porous plug in the centre, and make one side hot, leaving the other side cold, the gas passes from the cold side to the hot side. This is found to take place in houses, where there is a passage of gas through the walls of the building. Before I allude to this point further, I will just give

you an illustration or two of ventilation caused by the rising of the heated air. In every room where there is a chimney there is a source of fresh air, not down the chimney, but through the cracks in the windows and doors, and by the constant opening of doors, and thus fresh air thus entering drives forward the heated air, which has a tendency to rise, and drives it up the chimney. If we have no chimney in the room then this source of fresh air is practically valueless, because there is no escape for the vitiated air; and this may be illustrated by the jar which I have here with two candles. There is an entrance for the air below by cracks, the jar being raised 1–16th of an inch above the glass plate. The opening at the top is like the chimney in a room, the fire-place is below, the opening of the chimney is below here, and the taper burns steadily below the chimney. Here is a taper burning above what may be called the fire-place of the chimney, and as the vitiated air rises to the upper part in the bell-jar, it will in course of time vitiate the upper atmosphere, and so cease to support combustion, while the lower taper continues to burn as brightly as ever. That is already manifest here; the upper taper is languishing, while the lower one is burning brightly. Now it is out, the lower one burning as brilliantly as at first. Supposing we have a condition of things where we have no chimney, where the source of contamination is down below, such as we have in a coal mine, we must have fresh air entering somehow or other; if it cannot enter from below, it must enter from above. That it does enter from above is shown here, where I have what may be represented as a cellar or coal mine, this one tube representing the chimney of the cellar, and the other tube a staircase into it, or representing the up-cast and down-cast of a mine. That there is a draft down one chimney and up the other may be shown by the smoke traveling down the left-hand and out of the chimney where the light is. By stopping the down-shaft we may extinguish the light—the light is extinguished by reason of the want of air. That illustrates the ventilation of mines; and here is an apparatus which illustrates it much better, because this represents more nearly what is the actual state of things. A bell-jar with a chimney at the top, in other words a mine with a short shaft, is closed at the bottom so as to make it air-tight, with a little water, and after a time you will see the taper will by no means burn very brilliantly. It is not necessary for fresh air to go down a separate shaft into a mine or cellar, but it may go down the same shaft by which the foul air escapes; but, in order to effect that, if the air is perfectly still, the shaft must be divided, and that I propose to do as soon as the taper begins to languish. I will then introduce a division, which will cause the fresh air to enter down one side and the foul air to escape by the other. The taper is now beginning to die out; by interposing that division I shall cause it to revive. It takes a little time for the currents to establish themselves. Now, with a piece of brown paper, which gives me a supply of smoke, I will now find out which is the down-shaft and which is the up—down which side the fresh air is entering and which side the foul air is escaping. We have here very plainly shown the action of currents produced by the heating of the gases.

Now, the next part of the subject, the ventilation of a house by means of the passage of air through the walls, can be shown in an exaggerated form by the passage of hydrogen through a porous material. This is not to be considered by any means what takes place in a house, that is to say, we have not the passage of hydrogen, but we have a passage of cold air through the walls of a room into the house, and this experiment is made with hydrogen simply, because it is more easily shown to you than by any other means. Here is a porous vessel which may be taken roughly to represent the wall of a house, and if I bring this jar of hydrogen gas over the porous vessel, you will notice the passage of the gas through the porous vessel causes a pressure into this vessel, which ejects a stream of liquid. It has been proved, by experiment, by Pettenkofer, of Munich, that the passage of air through the wall of a house is very considerable. He examined the walls of an ordinary room in his own house, and found the change of air through the brick walls in a room, the

cubic contents of which were 2,650 feet, when the difference between outside and inside amounted to 34° F., amounted to this:

	Cubic feet.
	2,650
With a fire....................	3,320
All crevices stopped..........	1,060
With a difference of 7° Fah...	780
Window open 8 feet square...	1,060

This illustrates what takes place in winter, when one's repugnance to cold air causes one to shut the doors and windows and have a roaring fire. The air which cannot get in by crevices or by doors makes its way through the walls, that is to say, the doors and windows being shut, a certain increased amount of air passes through the walls into the room. What is the advantage of this? It is this, that we are supplied then with fresh air free from draft. Ventilation is not supplying fresh air, but supplying it free from draft, and this natural source of ventilation gives us really true ventilation. The amount of carbonic acid in the air may be taken on an average as about 4 parts in 10,000, and in order to keep the air fresh we should not allow the pollution of the air to extend to a greater quantity than 2 parts in 10,000 over this. Therefore, the extreme of carbonic acid in the air is 6 parts in 10,000. When the amount is more than this, the air begins to be close, that is to say, we begin to feel by the nose that there is a certain pollution in the air which you cannot exactly account for. Six volumes in 10,000 is the amount of carbonic acid which is allowable, and all above this must be considered unwholesome vitiation of the atmosphere. Then, in close places, that is to say, in places which contain more than 6 volumes in 10,000, of which there are many—workshops, offices, public buildings, theatres, all contain, generally speaking, much more than this—we have an atmosphere which can be known as unwholesome simply by the nose. The nose tells us there is something in the air which ought not to be there. What is the reason of this? It is not carbonic acid, because we cannot detect carbonic acid by the nose. It is a certain amount of organic matter thrown off from the lungs, and, generally speaking, from the body in some form or other, and this organic matter rises in proportion directly with the carbonic acid. Therefore, if we measure the amount of carbonic acid in the air we measure the amount of pollution by organic matter, and by determining the carbonic acid in the air, which we can do very accurately by chemical analysis, we also determine the amount of organic matter which vitiates the air. We do not know the organic matter, but we know there is more than there should be. In buildings in which the natural ventilation is not allowed free play, and in which no extensive mechanical appliances are used to contribute fresh air, this vitiation of the atmosphere goes on to a very great extent. For a few examples of this we have the analyses made by Dr. Angus Smith, and we find by this table that in workshops he has found the air so bad that it rose as high as 30 parts in 10,000; that is to say, the carbonic acid was very nearly ten times as much as it should have been. In theatres he found it rose to 32 volumes in 10,000 of air, in mines 78·5, an enormous quantity, and the largest amount he ever found was 250 in 10,000. Here is a table giving an analyses of air in different places, made by Dr. Angus Smith. In a Chancery Court, seven feet from the ground, with the doors closed, he found the proportion was 19·35 carbonic acid to 10,000; in the same court, three feet from the floor, 20·3; in the same building with the doors open, that is to say, when the fresh air had entered, it was 5·07 and 4·5. Then in the Strand Theatre, in the gallery it was 10·1, in the boxes 11·1; in the Surrey Theatre at 12 p. m., 21·8; in the Olympic, 8·17; in the Olympic in the boxes, 10·14; in the Haymarket, 7·5, and so on. In hospitals, where great care is taken to have large free space in the room for each patient, and a supply of fresh air regularly admitted, the amount does not rise above that of the outside air. In the Queen's Ward of St. Thomas' Hospital no more than in the outside air; in Edward's Ward of the same hospital it was 5·2. These tables show the large vitiation of air taken in crowded buildings, and in the case of the low courts it was almost as bad as any. There was another case, in the Queen's Bench, in which the air is described by Dr. Angus Smith as the foulest air that he ever found above ground.

It seems that law courts were always famous for being filled with foul air. In 1796, Brahmah, the inventor of the patent locks, who was giving evidence in a Chancery suit connected with one of James Watt's patents, complained that he could not give his evidence because he was "much incapacitated by those alkalescent and morbific exhalations ever consequent on large and close assemblies," no doubt the carbonic acid and the organic matter; and he complained that the judge's attention had "become flaccid through fatigue." This is really because of the small amount of air which is allowed to each person in the building—that is to say, the small cubic space which is available for each person's use—and, furthermore, that the amount of wall space is very small compared with the production of carbonic acid in the interior of the building. In summer, when the difference between the temperature of the inside and outside of a building is small, it is quite possible in a crowded room like a ball-room for the air to be more vitiated than in winter. Therefore, in theatres in summer we may look for a greater vitiation of the atmosphere than in winter, when the difference between outside and inside temperature is much greater. Acting upon this, last year I made some experiments at the two Italian Operas, Covent Garden and Drury Lane, and from several experiments made in each case, I found the following numbers: April 28th, Covent Garden amphitheatre, amount, 22·5 in 10,000 of air, near what is called a ventilator, although the air which was admitted was not pure, it was 17·6, and near an open door it was 14·8. The people in the building were listless and gaping, and evidently wanting in attention somewhat, and did not seem to be lively and animated, and they exclaimed how delightful was the fresh air coming in from an open door, yet this fresh air contained 4·8 volumes of carbonic acid in 10,000. In Drury Lane the average of three analyses was 25·9. You must not think that because these were taken in the upper part of the house that down below there was any great difference. In a private box, for instance, the space is so enclosed that the air very often there is worse than in the gallery, especially at the back of the box. In the stalls of Covent Garden, between the acts, when the curtain is down, the air is then very hot and very impure. I have not made an analysis of that, but one can feel it when the curtain is down; the supply of fresh air is practically cut off, because the supply of fresh air comes from behind the scenes, all other entrances being carefully closed by swing doors, and there being a great want of openings to supply fresh air from the outside. There is no doubt the large amount of gas burnt in a theatre, if ventilation had free play, would considerably facilitate the entrance of pure air. We have heard great complaints about public offices, more especially the British Museum; and last summer I made some experiments on the air of an office of which great complaints had been made, namely, in the money-order office in Aldersgate Street. In one room where there were a large number of clerks, a tolerably high room, with large windows, the proportion was 22.2 and something over, in fact it reached up to 25, this being the average of two or three analyses. This is as bad as a theatre. In the same office, on another occasion, without the gas lighted, it was 17·6. In the same office, with the windows open, there were 4·2 volumes, that is to say, it was practically the outside air. This gives you a tolerable notion of the amount of carbonic acid, and consequently the amount of pollution in the air in various buildings.

Now, with regard to the amount of fresh air which is necessary for each person. This is far more considerable than you would imagine. The amount of carbonic acid given off by an average size man in an hour, from the lungs and skin, is about 7-10ths of a cubic foot, and if we take it at 6-10ths we shall be below the quantity. A good oil lamp, or a couple of good candles, will also give 6-10ths of a cubic foot. Therefore, a man in a room with a lamp or two candles, gives one and one-fifth of a cubic foot in an hour. Now I have told you before that the amount of allowable pollution in the air was 6 volumes in 10,000; beyond that the atmosphere becomes unwholesome. Therefore, in order to keep the air fresh with two men in a room, or one

with a lamp or two lighted candles, would have to require this amount of carbonic acid produced with 5,000 volumes of air. He would therefore require 6,000 cubic feet of fresh air, and one man, therefore, in occupying a bed-room for instance, would require 3,000 cubic feet for his own use. This is pure calculation. What does the experiment show? In some experiments made in Paris to determine the amount of fresh air which should be supplied to hospitals it was found, by pure experiment, not by calculation at all, that this should be from 3,120 to 2,470 cubic feet in an hour.

	Cubic feet.	
Hospitals	2,120	
" for wounded	3,530	
" for epidemics	5,300	
Workshops.	2,120	
" for unhealthy trades	3,530	
Barracks, day	1,060	
" night	12,410	1,765
Large rooms for long meetings	2,120	
" short "	1,060	
Schools for children	424	530
" for adults	880	1,060

Now, in order to get this 3,000 cubic feet of air in an hour supplied to a large audience in any public building, it is absolutely necessary, as far as I know at present, to resort to some special means of supplying fresh air, and a very good instance of that is afforded at the Royal Institution. Very great care was taken, there four or five years ago by arranging with upright cylinders going to the roof from under the gallery, in which gas-jets were burnt, and passages connected with windows which entered underneath the seats and above the heads of the audience underneath the gallery, to admit fresh air; but, nevertheless, on a night when there is a large audience at the Royal Institution the air is undoubtedly bad. It is not so much, perhaps, the contamination by the breath as by the gas and heat—it feels extremely hot. To estimate whether the place is close or the air is polluted by breath, it is necessary to enter from the outside directly. That I have not done. I have gone in at the commencement, when the audience was arriving, and remained there to the end. Still, there is no doubt people complain continually about the air in the upper part of the building being extremely bad. There is no doubt that the Royal Institution, from the very fact that such care was taken in the ventilation, is far better than other buildings of the same kind, but it shows that, in order to supply fresh air to a building crowded in that way, some mechanical means must be resorted to. Such mechanical means are, so far as I know, a rotating fan, which drives air forward through pipes and distributes it to the building, and such a rotating fan is applied in America to the ventilation of hospitals on a large scale. In summer, when the air is hot, it is passed through ice to cool it; and when in winter it is cold, it is passed over hot-water pipes to warm it; and so a regular supply of fresh air is driven into the building, and allowed to find its way out where it can. In the Stamp Office at Somerset House, which is below the level of the ground, this means is resorted to, and I should imagine, in consequence of their having such a contrivance, that the air was in such a place wholesome. In this country it is not advisable to change the air of a room more than 4 to 6 times in the course of an hour. It is therefore necessary, generally speaking, to have a sufficient supply of fresh air to begin with, in order to prevent the air being changed too rapidly, and it has been calculated, as stated by Dr. Parkes in his book on "Practical Hygiene," that from 750 to 1,000 cubic feet per head per hour is necessary. In a crowded building where mechanical ventilation could be resorted to, the air could be so warmed as to produce no feeling of draught. I may as well mention what this feeling of draught is, and why it is that diffusion through the walls is unfelt. When the air travels at a lower rate than nineteen inches per second, generally speaking, that is to say, if it is not very cold, it is unfelt. There are around us continued currents of air pouring upwards by the heat of the body, causing the air surrounding us to become warm and rise up with fresh air coming against us; still these currents we are unconscious of. It is only by an extremely delicate instrument placed under your top-coat that these currents can be detected. Then on a day when not a leaf is stirring, not a ripple on the water, there are constantly currents playing about; these are unfelt, and are produced at a rate of some-

thing less than nineteen inches per second. That this rate is unfelt may be proved by passing the hand through the air at a speed somewhat less; and, of course, passing the hand through the air is just the same as passing the air over the hand if it were stationary.

Ventilation then may be considered, generally speaking, as the passage of fresh air to an apartment at a rate of less than 19 inches per second, so as to reduce the carbonic acid in the air to 6 volumes in 10,000. Dr. Angus Smith, who has done such valuable work in the matter of air and ventilation, gives us a means whereby we can estimate whether the air of a room is wholesome or not, whether the vitiation is increased to an extent which is unwholesome, and that is a very simple test. It consists in taking a bottle, which holds 10½ oz. of air when the stopper is placed in the bottle. If I blow the air into this with the bellows, and then take ½ oz. of saturated lime-water, the test consists of this, that if there is more carbonic acid in the air of that bottle than 6 in 10,000, shaking up this ½ oz. of lime-water in it will cause the lime-water to become turbid. Trying the experiment with the air of this room it becomes just turbid, and that is all. I should not think from this experiment that there were more than 6 volumes in 10,000. It just shows the slightest trace of turbidity and that is all. By taking a smaller bottle and the same amount of lime-water the amount of carbonic acid in the air may be told to the extent of one volume in 10,000, and by means of a flexible bottle and the lime-water contained in another apparatus, we may determine the amount with some degree of accuracy.

I will pass over the determination of the carbonic acid in the air, and I will go to another matter, a very important one, which is the carbonic acid in the soil. Pettenkofer has shown that if we take a gravelly soil, cut a piece out, and measure the amount of water that we can pour into it, the amount of water it will take up will amount to one-third the space occupied by the soil. Therefore, the soil consists of one-third of air. Now Boussingault has shown that the amount of carbonic acid in the air contained in the soil was very much more than that contained in the air of the atmosphere. He found that in a field recently manured it amounted to 221 parts in 10,000 of air, and in another field 974, and in a field of carrots 98, a vineyard 96, forest land 86, loamy subsoil 82, sandy subsoil 24, garden soil 36, prairie 179. You see then that what may be called the ground-air is highly charged with carbonic acid. When we warm a house by a fire it creates an upward draught, and undoubtedly the air from the soil passes into the house. If you doubt this, a very good case to prove it is the one Pettenkofer mentions at Munich of a house in which there was no gas laid on or any gas pipe within twenty yards of the house, yet the people in the house were poisoned by an escape of gas. This escape from the main traveled through the earth and gained admission to the house. Nearer home there has occurred a case of a still more striking character at Southgate, Colney Hatch, where one or two small houses were completely wrecked in November last by an explosion of gas. This gas was not laid on to the houses at all, the main passed through the street, the houses stood back from the street some distance; the main was cracked, the gas traveled through the soil, gained admission to the house, it smelt for several days, and finally exploded one evening on a lamp being lighted, and completely wrecked the building. Here, then, is striking evidence of gas passing through the soil. What does this teach? It teaches that the air of the soil should be as far as possible prevented from being polluted. If the soil is polluted by a leaky drain pipe we have that communicated to the soil which, if it gains admission to the house, may lead to disastrous results, the breaking out of typhoid fever, and those other diseases which are always traceable to contaminated air and water, which are familiar to every one. It is therefore highly important that this matter should have attention called to it. It is not at all an unusual thing in the neighborhood of London for speculating builders to build houses and make drain-pipes which have no outlet; they put drain-pipes below the house, which lead nowhere; the consequence is, that after the house is let the unfortunate tenant is perfectly ignorant of the fact

that everything which escapes by the drain-pipes is lodged in the earth. Of course, after a time, this cannot fail to be found out, but frequently only when it is too late.

Having mentioned this matter, I think I must now conclude my paper, and I hope sincerely that I may succeed in drawing attention to these matters which are undoubtedly of the highest importance. In preparing my experiments, I have to give my best thanks to my friend, Mr. Thomson, who undertook the trouble for me this afternoon, otherwise I do not think I could have performed them.

RAILWAY GAUGES.

From "Engineering."

UNDER the title of "Some Notes on the Early History of the Railway Gauge," Dr. William Pole has lately read a paper in which he strongly attacks the reaction towards narrow gauges now being so strongly shown in all countries where cheap railways are a necessity, and he goes so far as to state his belief that "the late official Indian narrow gauge movement will be pointed to by posterity as a blot on the mechanical character of the British nation. It will not only show, as Oxenstiern said, 'with how little wisdom the world is governed,' but it will serve as an illustration, added to many others, of how, in spite of the general spread of scientific knowledge, the most incomprehensible delusions may prevail." Further, Dr. Pole, after speaking of the introduction of the broad gauge, by Brunel, says: "Would any one, with this history before him, believe that a great economical policy had been based on the uneconomical proposal to push the wheels closer together under a carriage body? Yet the records of the past few years show that this has actually been done. It is said that a narrow gauge is cheaper; but this argues simply a misunderstanding of what gauge means, and what significance it has in railway construction." These are forcible opinions, and coming from an engineer of Dr. Pole's position, they merit a reply, notwithstanding that the errors they include have been fully shown by the results of practical experience.

We have no intention of discussing the historical portion of Dr. Pole's paper, but in order to explain the matter more clearly it would be necessary to state briefly the steps by which Dr. Pole arrives at the conclusions we have quoted. The 4 ft. 8½ in. gauge Dr. Pole states to have been adopted from the accidental circumstance of the Northumberland colliery lines being made to that gauge, and he goes on to remark that in the earlier rolling stock all the bodies were situated between the wheels, and that it was not until the traffic had been somewhat developed on the Liverpool and Manchester Railway that bodies extending over the wheels and axles with outside bearings came into use. This form of vehicle Dr. Pole characterizes as an "abnormal type," and "inherently defective in a mechanical point of view, and differing essentially from that which the experience of the world in all preceding ages had established as the proper one for wheel carriages." According to Dr. Pole, in fact, things were in a very bad state when Brunel stepped in to revolutionize matters by introducing the broad gauge. Brunel, he asserts, intended to place the bodies of his carriages between the wheels and to make the latter of larger diameter than usual with a view of diminishing friction, and under these circumstances the width of the gauge was determined so as to allow of placing between the wheels a private carriage, which was the broadest article ordinarily requiring to be transported by rail. As a matter of fact, however, the construction of carriages which Dr. Pole terms an "abnormal type" was, except in some of the earlier vehicles, adopted on the Great Western as on other lines, and the history of this point is judiciously referred to in the paper under notice, as "somewhat obscure." Dr. Pole, however, adheres to his proposition that the ordi-

nary type of railway carriage with outside bearings is mechanically wrong, that narrow gauge railways are a mistake, and that the gradual disappearance of Brunel's gauge, which he so highly commends, has been brought about not by any inherent defects in the gauge itself but simply from the evils of break of gauge which the Great Western Company had to suffer. On these points we propose to have something to say.

In the first place, as regards the construction of railway vehicles which Dr. Pole calls "abnormal," we entirely disagree from the conclusions at which he arrives. More than four years ago, in dealing with the stability of rolling stock (*vide* vol. x., page 439), we showed that when vehicles are "carried on bearings situated inside the wheels, the resistance to the overturning of the upper part of the vehicle on the springs is always less than that opposed to the overturning of the whole vehicle on the rails," and it thus follows that if the type which Dr. Pole so admires be adopted, the full stability due to the width of the gauge cannot be obtained. It also follows, as a collateral deduction from the above fact, that with inside bearings the springs used must be much stiffer than with outside bearings, to maintain the same control of the oscillations of the body, and that hence the outside bearings afford the means of producing a more easily riding carriage. Under the ordinary arrangement, too, the bearings need be made only about two-thirds of the diameter which would be necessary were they placed inside the wheels, and this, of course, proportionately reduces the axle friction. A third advantage is that by extending the body of the wagon or carriage beyond the wheels, a vehicle can be constructed having a less proportion of dead weight to paying load, than if the body was kept between the wheels, while the former mode of construction also enables a greater number of passengers to be carried per foot-length of train, and thus enables an economy to be effected in length of platforms at stations, etc. Altogether theory, as well as practice, points to the ordinary type of railway vehicle as being advantageous rather than "abnormal," while we are unaware of a single point of real superiority possessed by the type which Dr. Pole so strongly advocates.

We now come to the question as to the advantages of the narrow gauge lines which are now being so extensively built in almost every part of the world where railways are known. Respecting these lines our opinions are—as our readers scarcely need to be reminded—diametrically opposed to Dr. Pole's, and we have on many occasions entered into the matter so fully that it will only be necessary for us to speak concerning the salient points here. Dr. Pole insists that so long as the rolling stock is made to suit a given traffic the width of the gauge can make no material difference in the cost of the line, for he says, "the cost of the permanent way must depend upon the weight to be carried, while that of the overworks can only be governed by the dimensions of the loaded vehicles, into neither of which elements does the gauge necessarily enter." That he should insist upon such a statement as this is, we think, a remarkable exemplification of his own words already quoted, "how, in spite of the general spread of scientific knowledge, the most incomprehensible delusions may prevail." We should have thought that everybody conversant with railway construction and working was aware that the fact of a given traffic having to be accommodated by no means at once fixes the best proportions of the rolling stock to be employed. The proportions, in fact, are to a large extent dependent on the gauge, and are not, as Dr. Pole appears to suppose, dominant over the latter. It is quite true that in some intances the fact of certain articles having to be transported may fix the minimum width of vehicle admissible, but in all ordinary cases the width thus demanded is well within that which can be provided on such narrow gauge lines as we advocated, and such as are being made in India, so that this point does not enter into the discussion. As far as general merchandise is concerned the proportions of the vehicle used for conveying it can be varied within wide limits without introducing any practical inconveniences. It thus by no means follows, as Dr. Pole appears to suppose, that to accommodate a given traffic, the vehicles will, or ought to be, made of a certain width, whatever the width of

the gauge may be. On the contrary, it will be found that for every gauge there is a certain width of vehicle which gives the most beneficial results as regards proportion of dead weight to paying load, and necessarily this width becomes less as the gauge is reduced. This being so, Dr. Pole's assertions about the cost of permanent way and overworks at once fall to the ground, for the narrower the rolling stock the less is the weight per foot of train, and hence the less is the strain thrown upon the permanent way, while, of course, with a reduced width of wagons the less can be the span of the over-bridges. In other words, the adoption of a narrow gauge enables a certain weight of train to be distributed over a greater length of line than would be possible with a wider gauge, unless in the latter instance vehicles of a type which may be justly characterized as "abnormal" were employed.

Dr. Pole absolutely ignores the facilities which narrow gauge lines afford for economical management and working. Yet these matters are quite as important as the reduction of first cost. A reduction of the gauge is accompanied by a reduction in the size of vehicle which can be most profitably employed, and hence narrow guage rolling stock is not only more frequently run with full loads than the stock on a wider gauge could be, but the vehicles, whether loaded or unloaded, are more easily handled at stations, and thus a source of economy is introduced, which all who have had to do with railway management can well appreciate. As we have pointed out on former occasions, in fact, the lightness and handiness of narrow gauge stock leads to numerous sources of economy which it is impossible to enumerate here, but which should by this time be well understood by all who have studied the question.

Perhaps, however, the best answer to Dr. Pole's assertions respecting the policy adopted by the Indian Government regarding their new lines, is to be found in the every-day experience now being gained with narrow gauge railways. Everywhere almost we find such lines spreading. In the United States upwards of 2,000 miles of such lines have already been laid, while in Canada, South America, and our Australian colonies, narrow gauge railways have taken deep root. Nearer home, too, we find such lines constructed and in course of construction, in France, Germany, Italy, Russia, Norway, and Switzerland, and everywhere we hear good accounts of the results obtained from them. In a paper on the Rigi Railway, read before the Institution of Civil Engineers in 1873, Dr. Pole remarked that, although the railway in question "is in every respect a special and exceptional line, and intended for the very lightest character of traffic, the Swiss with their usual good practical sense have avoided the foolish fallacy of narrowing the gauge;" it, may, however, interest Dr. Pole to know that the Swiss "with their usual good practical sense" are not only now building metre gauge lines, but are also contemplating the introduction of narrow gauge tramways. The fact is that with very few exceptions narrow gauge lines have one great source of attraction denied to many of their more pretentious brethren. *They pay.*

It was at one time considered that it would be impossible for narrow gauge lines to provide the engine power necessary for carrying heavy loads or for working steep gradients. This, however, has now long been proved to be entirely a fallacy, the Fairlie system affording the means of placing, on even the narrowest lines, really powerful locomotives. Thus the Festinoig Railway of 1 ft. $11\frac{3}{4}$ in. gauge has now a Fairlie engine with 730 square feet of heating surface, while Mr. Fairlie has built engines with 829 square feet of surface, for the Patillos Railway, Peru, a line of 2 ft. 6 in. gauge, and others with 1,325 square feet of surface for the 3 ft. 6 in. Livny Railway, Russia. We have merely mentioned these out of numerous examples of narrow gauge Fairlie engines to show the capabilities of the system as already proved; but we may add that none of these examples represent the most that can be done on the respective gauges. If required, Mr. Fairlie would no doubt undertake the construction of still more powerful locomotives, and we may in fact say that the capabilities of the narrow gauge are now practically not in any way limited by the question of engine power. As we have frequently

pointed out, too, the Fairlie system and narrow gauge lines are intimately associated in several ways, for not only does the Fairlie system enable an engine power to be provided to an extent almost unattainable in any other way, but it also enables engines to be constructed which are eminently adapted for traversing the sharp curves generally to be met with on railways where first cost is an important consideration. This system of locomotive in fact enables the capabilities of narrow gauge railways to be fully developed, and we are glad to find that this fact is now being daily recognized, and that the advantage of narrow gauge are being appreciated by those who formerly regarded it as of very limited application, but who, throwing aside prejudice, have by further inquiry made themselves acquainted with the real truth of the case. In this number Dr. Pole does not at present appear to be included.

RAILWAY ACCIDENTS.

By FRED. CHAS. DANVERS, C. E.

From "Quarterly Journal of Science."

So much attention has of late been given to the subject of railway accidents, and the best means of preventing them, and so important is it in the interest of the public generally, that a few pages of the "Quarterly Journal of Science" may, with advantage, be devoted to a consideration of how far all known and practicable means for the mitigation of the dangers of railway traveling have been adopted. In investigating this question we must refer briefly, in the first instance, to the early history of railway legislation, with a view to trace what steps have been taken by the Government for the protection of travelers, prior to enquiry as to what action had been taken by the railway companies themselves with the same object.

The earliest railway or tramway Act was passed in 1801, for the construction of a railway from Wandsworth to Croydon, for "the advantage of conveying coals, corn, and all goods and merchandise to and from the metropolis and other places." From this period new tramways or railways were sanctioned in almost every session. The Acts by which the earlier railway companies were established followed very closely, in their general scope, the provisions which had been applied to canal companies. The promoters of the project were constituted a corporation, and were authorized to raise such money, either by shares or by borrowing, as they required for completing their undertaking; and they were empowered in their corporate capacity to take lands compulsorily, and to charge tolls at their discretion for the use of their railway, within the limits of certain prescribed rates, for various classes of goods. In the Act for the Liverpool and Manchester Railway, passed in the year 1825, and in other subsequent similar Acts, a further provision was introduced, that if the dividends should exceed 10 per cent. an abatement should be made from the maximum tonnage rates of 5 per cent. on the amount thereof for each 1 per cent., which the Company might divide over and above a dividend of 10 per cent. on its capital. In their capacity as owners of a road, railway companies were not intended by Parliament to have any monopoly or preferential use of the means of communication on their lines of railway; on the contrary, provision was made, in all or most of the Acts of Incorporation, to enable all persons to use the road on payment of certain tolls to the company, under such regulations as the company might make to secure the proper and convenient use of the railway. But no sooner were railways worked on a large scale with locomotive power than it was found impracticable for the public in general to use the lines, either with carriages or locomotive engines; and the railway companies, in order to make their undertakings remunerative, were compelled, with the

assistance of the persons who had been previously engaged in the carrying trade of the country, to embark in the business of common carriers on their lines of railway, and conduct the whole operation themselves.

In consequence of the increasing number of Railway Bills annually coming before Parliament, and the necessity of securing consistency in private bill legislation, the House of Commons, in 1837, appointed a select committee, to which were referred all petitions for private bills, and it was the duty of this committee to decide how far the standing orders had been complied with in each case.

In 1840, another Select Committee of the House of Commons, appointed to report on the railway system, came to the conclusion that the right secured to the public by the Railway Acts, of running their engines and carriages on the railways, was practically a dead letter. In consequence of their recommendation that the executive government should be entrusted with the duty of inspecting new lines of railway, and of exercising a general supervision over the manner in which the railway companies used their powers, an Act was passed by which it was provided that no new railway for the conveyance of goods or passengers should be opened without previous notice to the Board of Trade, and the Board were empowered to appoint officers to inspect all new railways. The Board was also empowered to require, under a penalty, that every railway company should deliver to them returns, in whatever form they might prescribe, of the traffic in passengers and goods, as well as of accidents attended with personal injury, and a table of tolls and rates from time to time levied on passengers and goods. All by-laws already made by companies were to be certified to the Board, and no new ones were to be made without its sanction. The Board was also constituted the guardian of the public interests, being empowered at its discretion to certify to the law officers of the Crown any infraction of the law, and the law officers of the Crown were thereupon required to take the requisite legal proceedings. The power which had been conferred upon proprietors of and adjoining railways by their private Acts of Parliament, for making junctions, was placed under the control of the Board of Trade, with a discretion to regulate the manner in which it should be exercised.

In 1842, the returns of the accidents required to be made to the Board of Trade were extended to all cases, whether or not they were attended with personal injury; and in 1844 parliamentary trains were established by law, and the powers of the Board of Trade to compel railway companies to comply with the law were extended to all unauthorized proceedings on the part of the railway companies. In 1846 an Act was passed establishing a Board of Commissioners of Railways, to whom the powers possessed by the Board of Trade were transferred; but in 1851 the Board of Commissioners was abolished, and its powers and duties were re-transferred to the Board of Trade.

In 1857 a Select Committee on Accidents on Railways was appointed, who in their Report of the 25th June, 1858, classified the causes of accidents under the three following heads: Inattention of Servants; Defective Material, either in the works or rolling stock; and Excessive Speed. Much stress was laid by the Committee on the necessity for punctuality in the departure and arrival of trains; they considered that it should be imperative on every railway company to establish a means of communication between guards and engine-drivers, and that a system of telegraphic communication on the lines should be enforced, in order that they might be worked on the block system; and they concluded by recommending that, with respect to signals, breaks, and other precautions, such details should be left to the management of the railway boards, but that the Board of Trade should be invested with further powers to enable them the more effectually to control the working of railways with a view to diminishing the number of railway accidents.

Bills have at various times been introduced with the object of compelling railway companies to adopt some precise system of working, but they were not passed; and in 1866, in a bill of this nature, it was for the first time proposed to compel railway companies to

adopt a means of communication between passengers and guards, and between guards and engine-drivers of all trains. This Bill, however, did not, at the time, become a law, but was withdrawn.

In 1865 a Royal Commission was appointed to enquire generally into the subject of railways, and to report, amongst other matters, whether, with a due regard to the progressive extension of the railway system, it would be practicable by means of any changes in the laws relating to railways, "more effectually to provide for securing the safe, expeditious, punctual, and cheap transit of passengers and merchandise upon the said railways."

Up to this date the legislation upon railways directed that no line should be opened until it had first been approved and passed by the Board of Trade Inspectors, but after it had been once opened for traffic the manner of working was left entirely in the hands of the railway company, power being, however, reserved to the Board of Trade to cause the railways, the engines, and the carriages to be inspected by their officers whenever they might think fit, and they might, when applied to, make regulations for the safe working of the traffic at the junction of the lines of two companies. The railway company, in undertaking the duty of carriers, became liable under the common law to compensate persons injured, and under Lord Campbell's Act to compensate the relatives of persons killed by the company's negligence or by that of their servants. Thus Parliament relied upon the principle of leaving the responsibility of the safe working of railways with the companies rather than upon giving the Board of Trade the power and duty of interfering in the details of management.

The Royal Commission of 1865, in their Report, expressed the opinion that the plan of relying for the safe working of railways upon the efficiency of the common law and of Lord Campbell's Act, had been more conducive to the protection of the public than if the Board of Trade had been empowered to interfere in the detailed arrangements for working the traffic. They recommended, however, that, on the one hand, railway companies should be absolutely responsible for all injuries arising in the conveyance of passengers, except those due to their own negligence; and that, on the other hand, the liability of the railway companies be limited within a maximum amount of compensation for each class of fares; but that any passenger should be entitled to require from the company any additional amount of insurance he might desire, on paying for it according to a fixed tariff. They also recommended that claims for compensation should not be admitted unless made within a certain period, and that the railway companies should have the right of medical examination of the claimant; and, further, that to the power already possessed by the Board of Trade of appointing officers to inspect railways and rolling stock, should be added a power for the inspecting officer to require the attendance of the officers and servants of the company as witnesses, and the production of books and documents bearing on enquiries directed by the Board of Trade; and that the reports of the inspecting officers on accidents should be made public.

In 1870 a Select Committee of the House of Commons was appointed to enquire into the law and the administration of the law of compensation for accidents as applied to railway companies, and also to enquire whether any, and what, precautions ought to be adopted by railway companies with a view to prevent accidents. On the second point the Committee pointed out that on those lines where the block system had been adopted it had materially conduced to the safety of the public, and they recommended the evidence collected by them on this subject, as well as that in favor of the principle of the interlocking of signals and points, and concerning continuous breaks, to the careful consideration of railway boards of directors.

Last year (1873) a Bill was introduced into Parliament for the "Regulation of Railways," with a view to the prevention of accidents. This Bill had for its object the enforcing upon all railway companies the obligation of securing an interval of space between trains following each other on the same line of rails, which is now generally effected by what is known as the block system, and it further proposed to enforce the interlocking sys-

tem. A Select Committee was appointed by the House of Lords to consider this Bill, but whilst strongly recommending the adoption of both the block system and the interlocking system on all important lines of railway, yet, relying on the great exertions recently and very generally made by different railway companies to extend both systems, and other great improvements now in progress, the Committee recommended that the Bill should not then be proceeded with. They recommended, however, that the Board of Trade should call for such information as might enable the inspectors, in their annual reports, to state specially the progress made in their adoption on all passenger lines, after which, it was considered, Parliament would be in a condition to decide whether or not it would be right to require the further and more prompt extension of these systems on those lines where they might still be necessary.

Another Commission is at the present time occupied in considering how railway accidents may best be prevented, and what legislation, if any, is desirable on the subject in the interests of the public at large. It will be observed that, hitherto, the action of Parliament has been rather to recommend and advise than to pass coercive measurers to compel railway companies to adopt improved means for the protection of their passengers. At the same time, additional powers have been vested in the Board of Trade from time to time for the more efficient inspection of lines open to the public, and there can be no doubt that the duties devolving upon that branch of public service have hitherto been conducted satisfactorily in the general interests, but it is hardly to be supposed that its action should meet with universal approbation, or, indeed, that it should be always free from blame. It is very obvious that the officers of the Board of Trade are not in good odor with the present President of the Institution of Civil Engineers; and, as his observations may probably be taken to represent the feelings of railway officials generally towards them, we quote the following remarks made by him in his inaugural address on the 13th of January last:

"There is also a 'popular delusion' which I think ought to be corrected. The public believe that the various recommendations made to the railway companies from time to time by the officers of the Board of Trade, such as the block system, interlocking of points, &c., are really inventions of those officers, whereas the fact is that not one of these systems or inventions, or any new idea in connection with the workings of railways, has ever really been suggested by them.

"The railway companies also are at a great disadvantage with the public in respect to the reports which are from time to time made by the Government inspecting officers—their dictum is never questioned by the public; and although railway officers of great experience constantly differ from those officials in the conclusions at which they arrive, the railway companies feel that any appeal against these reports is useless, and practically judgment is allowed to go by default.

"In making their reports, the officers of the Board of Trade are in the position of *ex post facto* judges, and I need hardly point out that there is a great difference, to use an expression of our late President, Mr. Hawksley, between looking into the events of the week that is past, and looking into middle of next week; and should the country at any time become the purchasers of the railways, these officers will soon find the difference in their position when the responsibility of working the lines devolves upon them.

"Captain Tyler, in his valuable Report on Railway Accidents in 1872, says: 'Whatever be the amount of care taken, the item of human fallibility will still remain, and will always be the cause of a certain number of accidents.' And he states that in 180 cases of accidents out of 238, 'negligence, want of care, or mistakes of officers, were apparent.'

"This is a subject to which for years past I have devoted a great deal of attention and anxious thought, and I attach much more importance to the item of 'human fallibility' than Captain Tyler appears to do."

To these remarks Captain Tyler replied as follows, in a paper read by him before the Society of Arts in May last:

"When Mr. Harrison attributes to the author that he does not sufficiently appreciate the element of human frailty as contributing to accidents on railways,

and leaves it to be understood that improved arrangements will not materially lessen the number of accidents and their serious results, the author would venture to reply that he estimates that cause of accident at no more and no less than has actually been found by experience of many years to attach to it."

This subject also was referred to by the Select Committee of the House of Lords, who, in their report of last year, remarked :

"It may be confidently stated that the general safety of railway traveling would be increased by the more extensive employment of the block and of the interlocking systems. Some witnesses stated that these precautionary arrangements and mechanical appliances tend to lessen the sense of responsibility in the engine drivers. Such an effect may have been produced, but, nevertheless, the advantages resulting from the introduction of these systems are practically admitted by all the witnesses, and, in the judgment of the Committee, decidedly preponderate."

We do not propose to follow up this subject further at present, beyond remarking that, whilst fully admitting the element of human frailty, which must exist wherever the hand of man is engaged, we entirely concur in the conclusion arrived at by the Select Committee of the House of Lords, that the introduction of improved machanical contrivances for the more efficient and safe working of railways is likely to overbalance in its advantages the evils likely to arise from the element of "human frailty," which must be, at all times, inseparable from their introduction.

The next subjects for consideration are the extent to which railway passengers are liable to accidents, and how far former risks are increased or diminished in proportion to the number of travelers, and to the adoption of means with a view to their prevention. A general review of the number of fatal accidents to passengers from all causes beyond their own control, between the years 1847 and 1873 inclusive, is contained in Captain Tyler's General Report to the Board of Trade on the accidents which have occurred on the railways of the United Kingdom during the year 1873, from which the following extract is taken :

"The total number of persons recorded at the Board of Trade as having been killed on railways during the year was 1372, and the number of injured was 3110. Of these, 160 persons killed, and 1750 persons injured, were passengers ; and the remainder, 1212 killed and 1360 injured, were officials or servants of the railway companies, or trespassers, or others who met with accidents at level crossings, or from miscellaneous causes. Of the passengers, 40 were killed, and 1522 were injured,from causes beyond their own control. The total number of passenger-journeys having been 455,272,000, it follows that the proportion of passengers killed was, in round numbers, 1 to 2,845,450, and of passengers injured 1 to 260,155 ; and that the proportions of passengers killed and injured from causes beyond their own control were respectively, 1 in 11,381,800, and 1 in 299,127. This was a decrease on the average of the number killed, and an increase of the number injured, from causes beyond their own control, in the previous three years, in which the proportions were 1 to 11,123,931 killed, and 1 to 357,000 injured. Of the officers and servants of railway companies there, have during the past year, in proportion to the total number employed, as nearly as they can be estimated (say 250,000), been killed from all causes 1 out of 323, and injured 1 out of 213 ; but accidents to servants do not appear, in many cases, even now to have been reported by certain of the railway companies, and their numbers would, if the whole truth could be ascertained, be considerably increased.

"The following statement shows the proportion of passengers killed to passenger-journeys for the three years ending 1849, the four years ending 1859, the four years ending 1869, and the four years 1870, 1871, 1872, and 1873, respectively : (*See table next page.*)

From these figures it appears that the average of fatal accidents for the last four years was higher than in the similar cycle immediately preceding ; and the conclusion that would naturally be formed at first thought is,that a maximum of safety in railway traveling has been arrived at. On a closer examination, however, it does not in any way seem that this is the case. No doubt traffic

Year.	Number of passengers killed from all causes beyond their own control.	Number of passenger-journeys, exclusive of journeys by season-ticket holders.	Proportion killed to number carried.	
1847, 1848, 1849	36	173,158,772	1 in 4,782,188	
1856, 1857, 1858, 1859	64	557,338,326	1 in 8,708,411	
1866, 1867, 1868, 1869	91	1,177,646,573	1 in 12,941,170	
1870	66	336,545,399	1 in 5,099,172	Average of these 3 years, 1 in 11,-123,931.
1871	12	375,220,754	1 in 31,268,396	
1872	24	422,874,822	1 in 17,619,784	
1873	40*	455,272,000	1 in 11,381,800	

has increased on may lines in a more rapid ratio than the development of increased accommodation for such traffic. But the accidents in 1870 were considerably in excess of the proportion given in the above table since 1856; but if we omit that bad year, and take only the average of the last three years, it will be seen that the number of passengers killed from all causes beyond their own control was only 1 in 20,089,993, which shows a considerable improvement upon any of the earlier periods referred to. The year 1871 was, it appears, exceptionally free from fatal accidents; but Captain Tyler shows that it is not desirable to lay too much stress on the results of working in the case of any particular year, either as to the number of sufferers or as to the number of accidents. More returns of accidents than formerly have been rendered by the companies within the last two years. Inquiries have also been instituted during those two years into a greater proportion of cases, and there is, humanly speaking, much of chance in both. A dangerous or defective mode of working is frequently carried on for a great length of time without bad results, while there are accidents and loss of life where greater precautions have been adopted, or less risk is apparently incurred. A comparatively trifling defect may in one case lead to much loss of life, whilst important defects may, in another case, be unattended with accident.

* The deaths of two of this number were not the results of train accidents.

Setting aside considerations of humanity, the railway companies have a positive and direct pecuniary interest in the avoidance of accidents, and capital laid out with that object in view is not likely to be wholly unproductive. Under Lord Campbell's Act the railway companies are pecuniarily liable to those to whom any injury is caused by accidents, &c., on their lines, and, during the ten years from 1848 to 1857 inclusive, there was paid as compensation on account of passengers and goods injured on fourteen lines of railway, no less a sum than £414,440, or at the rate of over £40,000 a year. For the five years ending with the year 1871, there was similarly paid £2,348,568, of which £1,622,370 was as compensation for personal injury, and £726,198 as compensation for damage to goods. These sums do not, however, include anything on account of injury to the servants of the railway companies, to whom the latter are not liable by law in the same way that they are towards their passengers or goods traffic.

The following table shows the number of train accidents that have formed the subject of inquiry, and have been reported on, by officers of the Board of Trade, during the past four years. The number of cases inquired into during the preceding five years averaged 83 per annum, upon which those for the year 1870 show an increase of 57 per cent:

1870.	1871.	1872.	1873.	CAUSE OF ACCIDENT.
9	19	21	24	From engines or vehicles meeting with, or leaving the rails in consequence of obstructions, or from defects in connection with the permanent way or works.
10	22	17	23	From boiler explosions, failures of axles, wheels, tyres, or from other defects in the rolling stock.
61	9	22	18	From collisions between engines and trains following one another on the same line of rails, excepting at junctions, stations, or sidings.
	63	91	98	From colisions within fixed signals at stations, or sidings, &c.
18	19	32	20	From collisions at junctions.
3	2	5	3	From collisions between trains, &c., meeting in opposite directions.
1	—	—	3	From collisions at level crossings of two railroads.
14	12	34	36	From passenger-trains being wrongly turned or run into sidings, or otherwise through facing points.
—	2	7	5	From trains entering stations at too great speed.
6	11	9	11	On inclines.
9	12	8	6	Miscellaneous.
131	171	246	247	

An examination of this table will show that the more serious classes of accidents are evidently upon the increase, more particularly from collisions within fixed signals at stations or sidings, and from passenger trains being wrongly turned, or run into sidings, or otherwise through facing points. But it must be observed that the accidents are in no respect proportionate to either the length of, or the amount of traffic on, any particular line of railway, some lines being particularly unfortunate in this respect, while others enjoy comparative immunity from accidents. Increase of traffice, high speed, and variations of speed, tend materially to increased risk, to greater numbers of accidents, and to more severe accidents when there is insufficient accommodation in lines and sidings, when signal and point arrangements are defective, when the means of securing intervals between the trains are defective, without sufficient break-power, without good construction and high maintenance, and when the appliances and apparatus are not adapted to the exigencies of the traffic. But when, on the other hand, the accommodation is sufficient to enable the traffic to be worked under safe conditions, when high speed is employed only over a good permanent way in suitable portions of railway, and under proper circumstances, and when good arrangements are made to preserve intervals between the trains, of whatever class, then such extra risk may be in a great measure obviated. Some of the great railway companies have made, and others are making, great progress in providing the necessary remedies. It was stated by Mr. T. B. Farrer, in his evidence before the Select Committee of the House of Lords last year, that the railway companies had then already spent upon the introduction of the block system and the system of interlocking signals, between £700,000 and £800,000, and that they were proposing to spend a great deal more; on a previous occasion, however, it had been stated before the same Committee, by Mr. J. S. Farmer, that, in his opinion, a great deal of expense had been thrown away in tinkering at the signals, in trying to do as little as possible, instead of grasping the thing comprehensively in the first place.

However much has already been accomplished, a good deal yet remains to be done, especially on certain railway systems; and Captain Tyler expresses it as his opinion that it is partly on account of sufficient attention not having been paid in previous years to the various means of safety that some of the great railway companies now appear so unfavorably at the head of the accident list, and partly also because they have found it difficult, with constantly increasing traffic, simultaneously to make

np for past omissions and to keep up with present requirements.

In a circular letter addressed by the President of the Board of Trade to the several railway companies in November, 1873, on the subject of the great increase in the number of railway accidents during 1872, Mr. Chichester Fortescue remarked that a large proportion of these casualties appeared to have been due to causes within the control of the railway companies. "If it may be contended," the circular goes on to state, "that the traffic on many lines has very greatly increased, and with it the risks of railway traveling, it is no less true that it is within the power of the companies to take care that the permanent way, the rolling stock, and the station and siding accommodation, are kept up to the requirements of the traffic; that the officers and servants are sufficient in number and quality for the work to be done, and that proper regulations for their guidance are not only made, but enforced; that pains are taken to test every reasonable invention and expedient devised for the purpose of preventing danger; and that such of those expedients as experience proves to be effective are adopted without undue delay.

"In the face of the facts collected and analyzed by Captain Tyler, and of the numerous accidents of the present year (many of them the subject of Board of Trade inquiries) it is difficult to suppose that such is the case.

"There can indeed be no doubt that methods of working and mechanical contrivances, the value of which has been thoroughly ascertained, have been too slowly introduced, and that there is great reason to believe that sufficient provision has not been made for the safe working of the increased traffic by the enlargement or re-arrangement of stations and sidings, and the laying down of additional lines of rail.

"But whatever may be thought of these and other causes as contributing to the result, the present insecurity of railway traveling imposes upon the railway companies the grave responsibility of finding appropriate remedies for so great an evil."

On the subject of the frequent unpunctuality of trains it was remarked, "The inconvenience, vexation, and loss caused to passengers by this breach of the conditions upon which the companies profess to carry them, constitute in themselves a serious subject of complaint. But the evil arising from unpunctuality does not end here. The surface of the line is disarranged; the chances of accident are multiplied; the trains are forced, in order to make up for lost time, to travel at excessive speed through complicated stations, or under other circumstances where such traveling may be equally dangerous."

It is further remarked that the returns of accidents to railway servants show a lamentable number of casualties, often fatal, in proportion to the numbers employed; and, finally, a hope is expressed that the railway companies themselves "will make every effort to meet the reasonable demands of the public and of Parliament."

The Board of Trade, as the branch of the Government which has to look after the interest of the public in respect to railway traveling, for which purpose it has been invested with special powers, could not with any degree of propriety have passed over, without some special notice, the alarming increase in the number of railway accidents recorded in 1872, which had increased nearly 44 per cent. over 1871, 88 per cent. over 1870, and 196 per cent over 1869. It is not proposed to consider, separately, the replies to this circular which were sent to the Board of Trade, as the remarks which they contained with reference to the principal causes of accident prevailing on railways, will be noticed further on under the different headings to which they respectively belong.

The means of safety which the accidents occurring last year show to be required, are thus given in the last General Report to the Board of Trade:

1. The judicious selection, training, and supervision of officers and servants, and the preservation of good discipline.

2. Maintenance in high condition of the permanent way.

3. Good design, construction, and material of axles.

4. The application of tyre fastenings which will prevent the tyres from flying off the wheels in the event of fracture.

5. Improved coupling of vehicles in trains.

6. Signal and point arrangements with modern improvements, including concentration and interlocking of the signal and point levers, and locking-bolts and locking-bars for facing points.

7. Safety points to goods or siding connections with passenger lines.

8. Increased use of the telegraph, with block-telegraph systems for securing intervals of space instead of illusory intervals of time only between trains.

9. Sufficient siding accommodation for the collection, distribution, and working of goods traffic, so that goods trains may be shunted and marshalled independently, and kept out of the way of passenger trains, and may not encumber and endanger the traffic on the main lines.

10. Continuous breaks, to be worked by the engine-drivers as well as the guards, as occasion may require.

We propose to consider these several means for providing increased security to railway traffic under the following headings, viz.—1. Efficiency of Staff. 2. Maintenance of Permanent Way. 3. Maintenance of Rolling Stock. 4. Signals and Points. 5. Telegraph, and the Block System. 6. Siding Accommodation. 7. Break Power,

1. *Efficiency of Staff.*—It will be readily understood that, all mechanical appliances for ensuring safety being perfect, the efficiency, both as regards strength of establishment and individual intelligence, on the part of the railway staff is yet necessary in order to secure freedom from accident and danger. Even under the most perfect organization, however, the fallibility of human nature must ever be a bar to the attainment of absolute security, but the risk may be lessened to the last practical limit by the maintenance of a fully efficient staff, and the strict enforcement of all regulations laid down for their guidance. In a paper on "Railway Accidents," read before the Institution of Civil Engineers as far back as April, 1862, Mr. James Brunlees, the author, observed that the negligence of servants, their payment, and their hours of working, were matters of the greatest importance, and he remarked that most of the accidents caused by negligence might be traced to ignorance or to inefficiency. The wages usually given by railway companies were too small to command the services of men of intelligence, steadiness, and self-reliance, and, in consequence, inferior men were employed, who were incapable of appreciating the importance and necessity of executing their duty with promptness and exactitude. In the official report to the Board of Trade on railway accidents for the year 1870, Captain Tyler remarked, after enumerating the accidents of the year under their respective headings: "Accidents from all the above causes are more or less preventible, except in so far as it will never be possible, under the best arrangements, altogether to avoid accidents from negligence or mistakes on the part of employees, although it is practicable, under good arrangements and systems, and with good discipline, very much to reduce their number."

In the year 1871, out of 171 investigated accidents, there had been in 121 cases of negligence, want of care, or neglect of servants; in 1872, out of 238 cases, 180 were due to negligence or mistakes of officers or servants; and in 1873, out of 241 accidents, a similar negligence was apparent in 182 cases.

Whatever be the means and appliances provided, or the amount of care taken, the item of human fallibility will always be the cause of a certain number of accidents. But the number of accidents from this cause, as was remarked by Captain Tyler in his report for 1873, may be very much reduced by "improvements in regulations and discipline, by greater care in the selection, training, payment, and employment of competent men in sufficient numbers and for reasonable hours, and by providing them with the requisite siding and other accommodation, with proper signal and point apparatus, with the best means of securing intervals between trains, with sufficient break-power, and with other necessary appliances." It has been argued that railway servants are apt to become more careless in the use of these improvements, in consequence of the extra security which they are believed to afford; but, whilst Captain Tyler remarks that by the results of more ex-

tended experience this argument has received further confutation, Mr. Harrison, the President of the Institution of Civil Engineers, and no mean authority on railway matters, stated, in his inaugural address, that there was an undoubted tendency on the part of engine-men and other railway servants to believe that all these arrangements of the block system and additional signals do, in fact, provide for their safety, and that consequently they do not keep the same look out, or use the same care that they would do on a line apparently less protected, "and that this is the case," he remarked, "observation and inquiry have clearly demonstrated."

Here, then, we find two leading authorities at issue in regard to a statement of fact, and it is, of course, very difficult to draw a fair conclusion between the two. The result of Mr. Harrison's experience seems to prove that, at present, railway servants have not become sufficiently experienced in respect to the true value of signals, and other means of safety on railways, but there is surely reason to hope that, as a body, they possess sufficient intelligence to enable them in time to appreciate more fully the extent to which these safeguards are valuable, and how much also depends upon their individual discretion.

In respect to enforcing discipline, Mr. Harrison observes that the difficulty is becoming constantly greater, as dismissal is no longer a punishment, when employment can at once be had elsewhere; and a reprimand is constantly met with the reply, "Oh! very well, I'll go." This gentleman has found that nothing attaches men more to the service of a railway company than giving them comfortable cottages, with gardens to cultivate.

The efficiency of a staff on a railway depends mainly upon three circumstances: First, the selection of none but respectable and tolerably educated men; secondly, the establishment of a fixed code of rules for their guidance, and seeing that those rules are strictly enforced; and, thirdly, the maintenance of an efficient number of men to do the required work; the payment of liberal wages, so as to keep them in the service; the holding out of prospects of promotion to the most efficient; and the proper treatment of them whilst in the service.

No doubt all modern improvements on railway working tend to increase the expense to the railway companies, but this is a matter for which there is apparently no remedy. "The question of the effect of the labor market on railways, both in their construction and working," says Mr. Harrison, "has come forcibly home to every one connected with them. It is not too much to say that all new works are now costing from 30 to 40 per cent. more than they did a few years ago, and nearly double the time is required to complete them."

As will be shown further on, the adoption of the block system on all lines will necessitate a considerable increase of staff for working it, and with these additional elements of "human frailty" there will evidently exist an increase in the numbers of those to whom the safety of the traveling public will be entrusted, and increased safety can therefore only be expected to result if the rules laid down for the guidance of the companies' servants are, in the first instance, judiciously framed, and afterwards rigidly enforced.

2. *Maintenance of Permanent Way.*—The accidents caused by defects in permanent way are, happily, not nearly so numerous as they were in former years. The art of constructing railways, in the first instance, and of properly maintaining them afterwards, is so much better understood now than formerly, that accidents arising from defects in its observance would be a great slur upon the professional officers of any company. In the year 1854, thirteen accidents occurred from the defective condition or neglect of the permanent way. In the following year thirty-one cases arose from the same causes, but in the year 1856 there were fewer accidents of this description, which fact may be attributed to the greater attention given by engineers to the permanent way, and to the introduction of the fished joint, and of other improved methods of connecting rails. In the year 1857 twenty accidents were caused by the neglect, or imperfect condition, of the permanent way; in four of these the permanent way had been neglected, and in five it had been con-

structed in a defective manner. In 1858, twenty-nine accidents, and in 1859 fourteen accidents, were due to the state of the permanent way.

In commenting on this class of railway accidents, due to permanent way defects, which occurred during 1870, Captain Tyler stated that only nine were attributable to the conditions of the way and works, or to obstructions on the permanent way, etc. "This," he observed, "is a great improvement upon former years, when, say ten years ago, 16 per cent. of railway accidents were caused principally by defects of permanent way; and the improvement is due, partly to the increased strength in some cases of rails and chairs, partly to placing the sleepers in some cases nearer together, and especially to the disuse of wooden trenails for attaching the chairs to the sleepers, and to the now almost universal employment of fish-joints for fastening the ends of the rails together." As to the remedy suggested for this class of accidents, it is remarked that next in importance to proper maintenance, and even as part of it, is the question of discipline amongst those employed in repairs, with a view to ensure, as far as possible, that due warning shall be given to engine-drivers when a rail has to be taken out, while the road is being lifted, or whenever the line is not in a fit condition to be run over at speed.

Twenty-six accidents occurred in 1871 owing to defects of construction. These defects, it was then pointed out, were not as promptly corrected as they ought to have been, as new materials were supplied, on many lines of railway; each company, or each individual officer, waiting too often to buy his own experience, and profiting too little by the experience of other companies. Defects of maintenance, which appeared in nineteen cases, occurred partly from the over-work of materials, and partly from the want of more careful supervision, and of more careful record and comparison, from which much valuable information might be obtained. The number of accidents due to defective construction of road or works was four in 1872, and six in 1873, and to defective maintenance of the same, sixteen in 1872, and twenty-four in 1873.

It may perhaps be considered that forty accidents in one year, upon all the railways in the United Kingdom, due to defective construction or maintenance, is hardly above the number that might be expected to occur from such causes, considering the vast amount of traffic which now takes place in the neighborhood, more particularly, of large towns and cities, but it must be remembered that these constitute a class of accident which is preventible by the exercise of due care on the part of the permanent way staff, and proper supervision during construction. It is, therefore, one which should not be seen in the official returns, unless accompanied by some such causes as exceptional floods, or other reasons to show that they were not occasioned by any laxity of duty or neglect of ordinary precautions on the part of the railway company or their officials.

Maintenance of Rolling Stock.—With regard to locomotives, instances do rarely occur—and they were more common in former than in recent years—of boiler explosions, due in some instances to want of proper care in the selection of water for their use, and in others, to a faulty mode of staying the boiler. These causes of accident are to be avoided by frequent inspection, by which the earliest intimation of any deterioration may be obtained, and the employment of weakened or worn-out boilers be discontinued. During the seven years from 1854 to 1860 twenty-one locomotives exploded, but in the annual returns to the Board of Trade only two accidents from this cause are stated to have taken place in 1870, and two in 1873; no record of a similar accident appearing in the two intervening years.

The most common accidents to rolling stock are the breaking of the axles and wheel tyres. These cases may be traced generally to one or other of the following causes: sometimes they occur in the winter months, owing possibly, in some degree, to the rigid state of the permanent way in frosty weather; some are due to the use of bad iron or steel, and others to defects either in the welding of, or in the mode of attaching, the tyres of wheels. The existence of flaws in either axles or tyres may completely escape detection until they are discovered upon the occurrence of an accident, and such

cases must be included amongst the risks which cannot be foreseen or avoided. The high speed at which trains travel as a general rule must subject both tyres and axles to very severe blows and jerks, especially when passing over points, or portions of line that are out of repair, and uneven, and it is in such cases that flaws or cracks are most likely to result in a complete fracture. "There is no satisfactory test," said Captain Tyler, in his report for 1870, "to which axles can be subjected from time to time in the course of running, as far as is known, by which flaws can be detected." With regard to fracture of tyres, it was stated in the same report that in two cases the tyre was attached to the wheel by means of rivets through holes bored in the tyre, and it was remarked that the "old system of boring holes through the tyres is essentially a vicious one, and is particularly undesirable in the case of steel tyres. It affords no security in the event of fracture, and even leads to increased risk of fracture, in consequence of the weakening of the tyre at the sides of the rivet holes.

In 1871 there were twenty-two accidents of this class, in which three persons were killed and thirty-four were injured; in 1872 there were seventeen accidents, occasioning the death of two passengers and five servants of companies, and injury to forty passengers and eight servants of companies, whilst in 1873 there were twenty-three accidents owing to the same causes, killing ten passengers and two servants of companies, and injuring fifty-four passengers and seventeen servants of companies. The chief methods recommended for adoption with a view to avoiding accidents from the breaking of tyres, consist in the use of improved modes of fastening them to the rims, so as to prevent them from flying off the wheel. They may fail from the brittle nature of the material, or from defects of manufacture, or from being too tightly shrunk on the wheel, and they have frequently failed from one of these causes, or from a combination of them. The danger consists, not in the fracture, or in the tyre becoming divided, whilst running, into two or more parts, but in the probability of the tyre, which is, or ought to be, in a state of tension on the wheel, flying suddenly and violently from it when fracture occurs, and this danger is greater with steel than with iron tyres.

3. *Signals and Points.*—During the seven years from 1854 to 1860 inclusive, as many as eighty-eight accidents happened from the use of improper or inefficient signals. Accidents have been caused by the total want of signals, especially at sidings, others have arisen from their defective form, or from their bad position. Many accidents have occurred in connection with distance signals; in some cases they have been placed so near to the station that the engine-driver has been unable to stop within the space allowed. It was observed by Captain Tyler in 1870, that out of sixty-one collisions, independent of the collisions at junctions or level crossings, thirty-one, or more than half of them, were due to defective arrangements with regard to signals or points, but that in twenty-eight cases out of these negligence was combined with the defects, and that the latter contributed more or less to the negligence; and out of eighteen collisions at junctions there were ten cases in which defective signal and point arrangements were the cause. In 1871 there were fifty-three accidents caused by defective signal and point arrangements, or want of locking apparatus; in 1872 the number of accidents due to similar causes was seventy-one, and last year it was seventy-eight, so that this cause of accident would appear to be growing rapidly in importance.

When trains were few, and the speed at which they traveled was moderate, a comparatively crude method of signaling sufficiently answered every purpose; with the increase of trains, the complications of junctions, and the greater difficulty that consequently existed in controlling a number of signals at any one point, it became necessary to place all the signals and point levers in or around the signal cabins; and, in order to afford a better view to the signal man, the cabins were raised to a greater or less height above the ground, and placed in convenient situations, according to local circumstances. But even then, when the control was more conveniently placed in the hands of one man, there was still, as the levers in or near a cabin became

more numerous, a liability to mistake, from the signalman pulling over a wrong lever; or the levers were fastened over by blocks of wood, which the signalman forgot to remove; and to prevent such mistakes, and serious accidents resulting from them, it became further necessary to interlock the levers with one another. By 1860 many improvements had been introduced upon the interlocking system, and the inspecting officers of the Board of Trade began to insist on the use of locking apparatus at the junctions of new branches with existing lines.

By the application of locking and other apparatus it is possible to prevent nearly all accidents from collision occurring, in the ordinary way of working, in consequence of any mistake of the signalman. Conflicts between signals, and conflicts between points and signals, may alike be avoided; and a good combination of locking-bar and bolt may be made to insure that the facing points are completely over before the proper signal is lowered, and may also prevent them from being moved during the passage of a train. It is, of course, impossible to provide against all the contingencies which may arise—such as, in certain cases, against the absolute neglect of drivers to pay attention to the signals made to them; or such as a signalman, when two trains are running towards a junction at one time, setting his points and lowering his signals first for one of them, and then altering them and preparing for the second train, without allowing time for the first train to stop short of the junction. But provision may be made, and is made to some extent, even for the contingency of an engine-driver neglecting to obey signals.

In a paper recently read before the Institution of Civil Engineers, by Mr. R. C. Rapier, a detailed description of signals and points was given, besides an account of different methods of interlocking the two, so as to avoid accidents which might occur in the event of wrong signaling. It would be impossible to follow out that paper in detail here, but we may briefly state that it was there shown that the mere connection of switches and signals was not sufficient, but that effective interlocking required the movement of the switches to be completed before the alteration of the signals could be made, and *vice versa;* whilst, as regards facing-points, it was stated that, although it was desirable to avoid them as much as possible on a line of light traffic, the use of facing-points, properly controlled, might be made one of the greatest safeguards where trains were frequent, and traveled at different rates of speed.

5. *Telegraph and the Block System.*—In two papers on "Railway Accidents," by Mr. Brunlees and by Captain Galton, read at the Institution of Civil Engineers in 1862, it was deduced from statistical tables that the great majority of accidents were attributable to preventible causes, and that, of these, 27 per cent. were due to the absence of the electric telegraph. The advantages of the telegraph in connection with the working of railways were dealt with in an able paper by Mr. W. H. Preece, which was read at the Institution of Civil Engineers as far back as January, 1863, and although all the views expressed by him on the subject at that time have not met everywhere with approval or adoption, the system generally has come to be recognized as absolutely necessary for the safe working of any line of railway, and it forms a most important element in the now universally adopted block system.

The first attempt of a block system introduced on railways was by maintaining a presumed time interval between trains; this plan, however, failed, because those intervals could not in practice be observed; and the permissive system for reducing the time intervals by the aid of the telegraph, and sending trains timed to travel, and capable of traveling, at various speeds, one after another, into the sections, with a caution to each, may also be considered to have failed, because it does not afford sufficient protection to the traffic. Under these time systems collisions have occurred from engine-drivers slackening their speed to avoid collision with trains in front of them, and being run into by trains behind them. The greater the variety of speed between the trains, the more does the weakness of such systems become apparent.

The proposal to divide the line of railway into telegraphic sections, and thus

to preserve space intervals between trains, was made by Mr. (now Sir William) Cooke, as far back as 1842, and was first practised, it is believed, on a portion of what is now the Great Eastern Railway, in 1844; and, subsequently, a train telegraph system was established on portions of the London and North-Western Railway. This latter, however, was not a block system, or a space system, but a time system worked with the aid of telegraph instruments, and it is now known as the permissive system. As regards the block system, there are many descriptions of instruments for working it, and various rules and regulations applicable to it on different lines of railway. The main principle involved is simply by the division of a line into block sections, and allowing no engine or train to enter a block section until the previous engine has quitted it, to preserve an absolute interval of space between engines and trains. This may be done mechanically or electrically. Any means of communication with which the signalmen may be provided will enable them to inform one another of the approach of a train, of its entrance into a block section at one end, and of its exit from that block section at the other end.

Mr. Harrison, the President of the Institution of Civil Engineers, has stated that the block system will, as soon as it is possible to complete the necessary works, be introduced throughout the whole of the railways in England. It was stated by Mr. Farrar, before the Select Committee of the House of Lords last year, that the railway companies had already spent upon introducing the block system, and the system of interlocking signals, between £700,000 and £800,000, and they were proposing to spend a great deal more. Besides this expense there is a considerable annual cost to be incurred in working those systems; the increased cost of the staff alone is estimated for the Great Eastern Railway at £13,860, and on the Midland at £130,000 per annum. In the case of the North Eastern Railway it is calculated that on the completion of the block system, the number of signalmen will be increased from 500 to 2,000. Mr. Rapier, in his paper to which we have already referred, shows that the probable cost of the interlocking and block system on fourteen of the principal railways would be about $\frac{1}{2}$ per cent. on the whole cost of the lines, and that then their carrying power might be so increased that three times as many trains could be run on the block system as without it, and with greater safety. The probable cost of maintaining the block system was stated to be about $2\frac{1}{2}$ per cent. on the traffic receipts, and this comparative percentage was less on the lines which had a great number of points to protect than on some of the light traffic railways.

6. *Siding Accommodation.*—It was pointed out in the Report to the Board of Trade on Accidents that occurred during 1871, that collisions at stations often occurred from the want of accommodation at the stations or sidings, passenger lines being unduly obstructed from the want of sidings in which to place slow or stopping trains, or in which shunting may be performed. The same deficiency of accommodation may also be the indirect cause of collisions on the line between stations, when, for instance, from the want of siding accommodation, a slower train is despatched in advance of a faster one, without a sufficient interval between them to allow of its proceeding forward to the next place of refuge before it is overtaken, and it is stated that the want of improvement in, and addition to, the siding accommodation, combined with the want of modern appliances for working the points and signals from suitable cabins, and interlocking the levers with one another, and of telegraph-working for assisting in protecting an obstructed station, have principally to answer not only for the accidents themselves, but also for the negligence of the servants by which those accidents were more or less directly occasioned.

7. *Brake Power.*—The subject of brake power is one of especial importance, many lives and much property being hourly dependent, in a greater or less degree, on the power and efficient state of the brakes. It has been found that most of the collisions which have occurred might have been prevented had those in charge of the trains possessed the power of stopping within a few hundred yards. This is more par-

ticularly necessary on account of the high speeds and heavy trains now adopted on all lines. It is therefore essential that there should be ample brake power to each train, and, whatever system may be adopted, it should be powerful, simple, and capable of being applied in the shortest possible time. On certain railways, where the necessities or convenience of the companies have been the means of inducing more rapid improvements in this respect, systems of continuous brakes have for many years been in successful operation; and the experience of these lines has left no doubt of the value of such systems of brakes. Amongst the simpler means of providing extra brake power are: increasing the numbers of guards and of brake vehicles; enabling a guard or brakesman to apply the brakes of two adjacent vehicles; allowing the guards and brakesmen to walk through the trains, and to apply the brakes of the various vehicles provided with them; or by such a system as may enable a guard from his own van to apply the brakes of several vehicles, in which may be combined an economy in guards with efficiency in brake power. In the use of any good system of this description, it becomes unnecessary to skid the wheels of brake-vehicles, and flat places in the wheel tyers are thus avoided. Perhaps the most perfect system of continuous brakes yet introduced is that which enables the engine driver to control the train, and by means of compressed air to apply all the brakes at once without the development of any manual exertion.

The limit of space to which we are necessarily confined for a single article has prevented any detailed account of the various methods of intercommunication in trains, which, by the Regulation of Railways Act of 1868, is directed to be provided in every train carrying passengers and traveling more than twenty miles without stopping, or of the several other minor arrangements suggested or introduced, with the view of more effectually securing the safety of passengers.

With the adoption of the improved methods of interlocking signals and points, and of the block system, no doubt very considerable addition is made to the safety of travelers, but the companies are thereby put to great additional expense, both in first cost and for subsequent maintenance, for which the only return they can look to is an increased immunity from accidents. To insure absolute security is not, however, possible, by the adoption of any means hitherto suggested. The introduction of the block system necessitates the maintenance of a considerably increased staff of signalers, and at the same time it introduces so many additional elements of human fallibility, whose liability to err can only to a limited extent be guarded against by the employment only of competent men, and the strict enforcement of such rules and regulations as it may, in each case, be considered advisable to frame for their guidance.

THE FUTURE OF ARCHITECTURE.

From "The Builder."

Recent discussions have shown that there is no desire on the part of the profession to disguise the defects, the demerits and the failures, which have in so large a measure exhibited themselves in connection with our modern architecture, and the system to which we are indebted for our architects. The main practical conclusion we have now to face is that the production of our architecture has passed into the hands of an immense multitude throughout the country, of whom it is impossible to say that they are the fittest minds for the task they have undertaken, or, that if so, there is any guarantee of their qualifications. This is a condition of things with which it is impossible immediately to deal; any amelioration must be gradual, progressive and prospective. No system of compulsory examinations could be set up, or the absolute necessity of a diploma before practice enforced, as things now are; and we fear that the offer of voluntary examination, and the advantages which might accrue in professional

status by being fortified by such a guarantee would be responded to a very slight extent. Hence, as we have said, any remedial measures must be regarded chiefly in their prospective aspect. What we have now to determine is, whether we can fairly and safely hope that there are elements in the present condition of things, which will, if slowly, yet surely, work their own cure. In the present intermingling and jostling, as it were, of engineer, builder, and architect on the same field, may it be hoped that the gradual improvement of public taste, and a higher tone in the patronage upon which architecture depends, will eventuate in a demand which will be unable to tolerate that which now passes for sufficiently good architecture, and in the end so far eliminate the bad, that false, mediocre, and pretentious work will sink to its level, and that which the true architect can alone supply meet with its fitting place? We are very distinctly of opinion that it is fallacious to indulge such a hope. It must be a fact within the knowledge of all who have thought upon fine art in any of its branches, be it architecture, painting, sculpture, music, or poetry, that "taste" is a most variable quality, and grows by that which it feeds upon. Illustrations innumerable might be given as to this, but we will confine ourselves to a single cognate instance. Can there be a question that, even among minds of an average range of culture and susceptibility to æsthetic influence, that after being accustomed to a low type of art, say in architecture, and perfectly satisfied with this, because knowing no higher or better, the sight of indubitably finer buildings would at once raise the taste, and render that before tolerated with complaisance almost insufferable. Now, this we take to be the key of the whole question of an advance in the public taste as to art, and it decides at once what we believe must be found to be the truest ground upon which any hope can be built, that the "architecture of the future" will prove any positive advance upon what is now in its main extent a somewhat mongrel and unsatisfying state of things. The public taste can become debauched or perverted by showy, pretentious work, which will not bear investigation upon any principles of true architecture; and which, if capable of startling and creating a "sensation," will not answer to that one criterion of true art, it sufficing to afford an abiding source of pleasure. All this character of art is increasingly abundant around us, for evidence of which we have only to point to the majority of new edifices which arise in the process of rebuilding now so rapidly going on. The issue of all this cannot be such a purifying and ennobling of public taste and art-patronage as will lead to the production of works which will stand the test of lasting admiration, but rather their degradation, and will leave few precedents to posterity such as the thoughtful, noble works of Greek and Mediæval times have been to subsequent ages. How, then, are these tendencies to be corrected and the foundation laid for a pure and noble system of art-culture and development? While our architects, or the large body who undertake our architectural works, are either incapable of anything better, or persist in pandering to a false taste, there *can* be no improvement, and the present conditions of patronage are such that the chances are that the meretricious will outbid a higher and truer class of art. Nor will improvement come, as some fondly imagine, by a dissemination among all classes of some knowledge of the principles and practice of art. The *utmost* that can be done in this way will go so little towards forming a correct taste that it cannot be taken into reckoning with what we have stated to be the practical means which creates, fosters and maintains true taste in art, viz., the exhibition of instances of such noble works as gradually, if not at once, make themselves felt, and adjust the standard of what is satisfying against inferior and ignoble work. The consideration of this question has often been before us, and we can only resort to what we have already stated, that, in the present condition of English architecture, the admitted failure of the pupil-system, the impossibility of enforcing a system of examinations and degrees, and the fact that our present architecture is in the hands of such a numerous band of practitioners and aspirants, there is no *immediate* prospect of the application of any means which can act as a direct remedy. But there is a *prospective* one,

and this we think, to all who give the subject a candid and thoughtful attention in its present aspects and bearings, will be found to consist in the establishment of architectural colleges. These would provide an arena for the combined and sustained study of architecture in all its fulness as a fine art unaffected by the chance influences of misapplied patronage and misinformed public taste to which our architects are now necessarily subject, and, if rightly organized, would attract only that class of minds which find in architecture an expression of the art-faculty with which they are endowed. The cultivation of any art beyond the limits of those who can enter upon it with some sort of original creative faculty is a mistake and waste of effort, and in modern times has given us that plethora of mediocrity in nearly all the fine arts which has been their bane and misfortune. But architectural colleges of the nature we have in view, would send forth trained bands of men agreed upon the common principles at the base of all architectural practice in varying constructive modes and the unity of decorative effects ; which, as matters of ascertained truth could not be diverged from, as now, at the dictate of any caprice ; while leaving a full field for the exercise of that individuality and originality which must ever form a considerable factor in all true art.

It is comparatively easy to point out the defects of our present architecture and the system which promotes them, and, by a converse process, to arrive at what might be regarded as an ideal condition of things, which might well be taken to be such a state of the public taste as could not tolerate the exhibition of bad architecture ; and hence the necessity that our architects should be only those who could satisfy such a high demand. But, as we have seen, the cultivation of the public taste is the direct product of that which is placed before it, and higher results can only be attained by beginning with those in any age and nation best calculated to be the purveyors of art to those who have it not. There is one all-important point in regard to architecture which applies with less force to the other fine arts. An architectural work, whether we will or not, *must* come under our notice, and must exercise an influence from which we cannot escape, either for good or evil, in the elevation or lowering of our taste. Herein lies the *raison d'etre* for seeking to confine the production of our architecture to the best minds and hands; and, after the fullest consideration of the whole subject, in view of the actual condition of things amongst us, there seems nothing which offers any prospect of a remedy other than the combining of the best contemporary genius and talent in the study of architecture in such a form as shall be able so to take the lead that the public will not be long in judging what are the true art-products and what are not, and in rendering honor and aid to those alone entitled to deserve them. A system of architectural colleges effecting this result would soon winnow the chaff from the wheat, and be able to dispense all those distinctions that are now wanting in the architectural profession.

We cannot but regard the present as a time of crisis in the history of architecture in this country, and though we have before in a detailed manner pointed out the place and special value of something of an architectural collegiate system for the satisfactory cultivation of the art, and the formation of a genuine architectural profession in the midst of the divided heterogeneous influences of the present time, we would again commend this aspect of the subject to the earnest attention of our thoughtful professional readers. Art now stands in a different relation to society to what it did in any former time ; we cannot restore old conditions, but must meet the new ones as best we may, and the two points which have now to be conciliated, are the providing scope for the best art-faculty amongst us, and such a cultivation of the public taste as shall reduce patronage of the inferior and mediocre to a minimum. A well-organized system of colleges, whether affiliated to the universities or not, would effect the one, and general art-congresses in their public and popular aspects would do not a little in effecting the other. It is to be hoped that the admirable bequest of Chantrey for the encouragement of the highest art in painting and sculpture may meet with some imitator in the interests of

architecture ; a similar sum in trust in the hands of a few of our most devoted and distinguished architects and connoisseurs would go a long way towards setting on foot an influence upon our architecture such as the present mercantile and fictitious repute notions which govern its patronage can never afford.

BREECHLOADING ORDNANCE.

From "Engineering."

In a recent communication to the *Times*, through Mr. Alfred Longsdon, Herr Friedrich Krupp, of Essen, has contributed some valuable information upon the subject of cast steel breechloading guns, information which no one was in a position to supply but himself, the largest private maker of ordnance in the world. The main object of this letter was to throw some light on the confused notions existing as to the powers of resistance of cast steel guns, and the reliability of the breech mechanism employed. With respect to the rumors that in the course of the Franco-German war 200 field pieces failed, we are assured that not one gun burst during the whole of the campaign on the German side, which was supplied wholly from the works at Essen, while the breech mechanism in all cases showed its complete efficiency, and not a single failure of it is recorded.

Mr. Longsdon next, taking wider ground, gives us statistics as to the failures which have taken place among the 13,000 steel guns manufactured by the magnificent establishment he represents. These failures, he assures us, are limited to seventeen. Out of this extremely small number eleven may be fairly thrown out of consideration; they were imperfect guns as far as the breechloading mechanism was concerned, having been made, tested, and destroyed before the present highly efficient system of breechloading had been adopted. Of the remaining six guns Mr. Longsdon gives us a record as follows:

In 1865 a 9-in. gun burst explosively in Russia after the 410th round. This gun was a converted muzzleloader, and failed under excessive charges.

In 1866 a second 9-in. gun burst explosively in Russia after the 56th round.

In 1869 an 8-in. gun burst explosively in Berlin after the 650th round.

In 1871 an 11-in. gun burst at Fort Constantine.

In 1872 a 15-pounder burst in Berlin after 557 rounds.

Mr. Longsdon has, however, omitted to mention several other failures of his guns, which we may add to the above list. We take them from a paper read by Major Haig before the Royal Artillery Institution.

In 1865 a Krupp 9¾-inch steel gun burst with a moderate charge of powder, a Prussian committee attributing the failure to inferiority of the metal.

In the same year a 9½-in. gun of Krupp's steel burst in Russia at the 66th round.

In the same year an 8½-in. similar gun burst at the 96th round.

In 1866 a Krupp field gun burst explosively at Berlin, killing three cadets.

In 1866, during the Austro-Prussian war, six Prussian steel field guns burst.

In January, 1867, a 7-in. Krupp gun burst at the second round of proof at Woolwich.

In the same year a 4-pounder burst at Tegal, near Berlin.

In 1868 an 8-in. Krupp gun burst on board a Russian frigate very destructively, killing and wounding in all 12 men.

In 1872 an 11-in. Krupp gun burst at the chase, and blew about 3 ft. off the muzzle.

The correctness of the above list is easy of verification, and it is somewhat to be regretted that Mr. Longsdon should have overlooked these important instances of dangerous failures, as they modify considerably the inferences to be drawn from his letter. In statistics of this kind nothing is so necessary as unassailable accuracy; and we should be

glad to learn that Major Haig's statements are incorrect, although we have not the slightest doubt that the failures enumerated by him did take place, and the value of Mr. Longsdon's communication to the *Times* will lose all its value if we find that the assurances it contains are unreliable. And before accepting the assurance that no Krupp field guns failed during the Franco-German war, we are obliged to hesitate, because since the publication of Mr. Longsdon's letter, the public is assurred that in numerous instances the Krupp field guns have burst during that period.

One correspondent, replying to Mr. Longsdon's letter, states that in 1871 he was assurred by an officer on the Headquarters staff of the German army, that out of 70 long breechloading 24-pounders, 36 became unserviceable during 15 days' firing, and that had the bombardment been continued for another week, the German batteries would have been silenced owing to failure at the breech. Again on the Loire and in Brittany 24 field guns became unserviceable, chiefly through their own fire. A second writer goes further and maintains that about 200 field guns were wholly or partially disabled, two or three through the enemy's fire, and the rest through defects in the breech mechanism and bursting of shells in the bore. It is only fair to state, however, that these damaging allegations are advanced anonymously, and require corroboration.

We have to assume, therefore, despite Mr. Longsdon's assurances to the contrary, that a considerable number of explosive failures of Krupp guns have taken place; but we would call attention to the fact already recorded by us, that none of them are proved to have failed by reason of the breech mechanism (after it had attained its present form), but through the unreliability of the metal itself.

From the experience thus gained it may be fairly assumed that the steel employed in the heavy ordnance on the Continent is not so reliable as the steel and iron used in combination in our Woolwich guns. A steel gun may show very high powers of endurance, as evidenced by many admirable examples of Krupp's work, but it is impossible to be absolutely sure of the absence of any flaw or other unseen element of weakness, and when it does yield, it almost certainly yields with violence. Sir Joseph Whitworth claims, and indeed has shown by numerous experiments, that the homogeneous metal he manufactures is entirely reliable, that it exhibits very high powers of resistance, and when forced to yield by the overwhelming nature of the powder charge it does not break with violence. But for all practical use to this country the employment of this metal has not gone beyond the stage of experiment, and we fail to understand why it has not been tested in the A tube of one of our large Woolwich guns. The Woolwich authorities are, we feel sure, anxious to adopt superior materials whenever possible, and, therefore, they can scarcely be responsible for not having tried a metal, which is, according to the high authority of Sir Joseph Whitworth, far superior to any that has ever before been employed.

But even with the materials at their disposal the guns made at Woolwich show no such annals of explosive failure as do those of Essen manufacture. Indeed, the great merit of our heavy ordnance is its almost perfect non-liability to burst explosively, but that it yields gradually, giving timely warning of approaching failure. The admirable combination and arrangement of material used in the Woolwich guns is equalled nowhere, and in our present state of knowledge cannot be surpassed, and the reasoning in the Text-Book of the Construction aud Manufacture of Rifled Ordnance, published in 1872, holds equally good to-day. "Steel from its hardness, high tensile strength, and freedom from flaws and defects, is better suited than wrought iron for the inner barrel of a gun, while its brittleness and uncertainty render it unsuitable for the exterior portions. The construction adopted in the service is, therefore, founded on correct principles, as far as the materials and their arrangements are concerned, and the correctness of the principles has been proved by twelve years' experience, during which period thousands of guns have been manufactured and issued, and in no one instance has a gun burst explosively on service, nor has a single life been sacrificed." Of the ordnance of no other great power in

the world can this be said, and whether we compare our guns with the composite cast iron and steel structures of France, the steel guns of Germany and Russia, or the obsolete cast iron pieces of the United States, our superiority of design, of materials, and of workmanship, is as marked as it is reassuring. That reforms may have to be made in our mode of rifling, and that possibly, nay probably, we shall follow the practice of Continental nations, and abandon muzzle in favor of breechloading for large calibres, does not alter the main fact of the superiority of our heavy guns.

The durability of the breechloading system, which we have described and illustrated on previous occasions, has, as we have stated, been called into question by the correspondents to the *Times*, whose letters was called forth in reply to Mr. Longsdon's communication. The evidence on this point, however, is very vague, and on the other hand there is very powerful testimony in favor of the system. To apply it to one of our heavy guns will be (if such a decision be arrived at) but a small matter, and we shall then have ample opportunity of judging for ourselves of the actual merits of the mechanism as carried out at Woolwich.

At the close of his letter to the *Times* Mr. Longsdon refers to the claims of Mr. L. W. Broadwell, of Carlsruhe, to the invention of the breechloading mechanism associated with Mr. Krupp's name, and as we have on previous occasions referred to the same subject, his remarks have a special interest for us. But as Mr. Longsdon has favored us with a communicttion touching the same question, and dealing with it in much detail, we propose only to make a passing reference to the matter now, and to defer our criticism of the letter addressed to ourselves until Mr. Broadwell himself has been allowed time to reply.

Mr. Krupp, writing by Mr. Longsdon, accedes to Mr. Broadwell the invention of a detail originally connected with the system, a detail obsolete indeed, but which at the time was of considerable importance. "To Mr. Broadwell belongs the merit of *inserting the ring in the face of the breech block*, a very useful invention." The italics are our own. This detail was patented by Mr. Broadwell in 1861, yet in 1862 we find precisely similar rings inserted in the breech blocks shown in Mr. Krupp's specification. Thus while a clear acknowledgment is made of the fact that Mr. Broadwell was the originator of the idea for placing the ring in the face of the breech block, endorsing our own statement, we have no explanation why the same detail was patented by Mr. Krupp more than a year after.

But we are assured that the "Broadwell ring" is a misnomer, it "wrongly goes by his name," and should, by inference, be called the Krupp ring. Reference must be made here, we presume, to the perfected form of ring, patented by Mr. Broadwell in 1865, and improved subsequently. Yet in Mr. Krupp's specification dated February, 1865, two months before that of Mr. Broadwell's just referred to, we only find drawings of the ring inserted in the face of the breech block, the "very useful modification," the merit of which belongs to Mr. Broadwell. In the latter gentleman's specification dated April, 1865, the first arrangement of a specially formed ring fitting in a suitable channel in the bore of the gun, and bearing at the back upon a circular plate in a recess in the breech block, is shown. For many months before this patent was applied for, Mr. Broadwell had been in St. Petersburg, discussing his plans for breechloading ordnance with the Minister of War, and it was while there that he introduced this improvement on his original idea. In July, 1865, about three months after his application for a patent, the Russian Government had accepted his system, with a formal declaration of which the following is a translation. "After numerous experiments made by the Imperial Russian Government in the gas check ring, the invention of Mr. L. W. Broadwell, citizen of the United States, this ring has been recognized as perfectly attaining its object of preventing the gases from the burning powder to escape through the transverse opening in the breech, through which the closing mechanism is introduced, and it is in consequence of these highly satisfactory results that the said Broadwell ring has been introduced in the Imperial Artillery, for use in cast-steel breechloading guns. (Signed) Barantzoff, Aide-de-Camp Gen-

eral." Thus, while Mr. Krupp freely acknowledges the originality of Mr. Broadwell's insertion of the ring in the face of the breech block, dates and unquestionable authority award him the undoubted merit of the improved ring, universally known by his name.

We have dwelt at some length upon this point, having been led to do so by the remark we have quoted from Mr. Longsdon's letter to the *Times*, and here we leave the subject for the present.

We would, however, take this opportunity of assuring Herr Krupp and Mr. Longsdon that the only object we have in view, is to arrive at, and place on record the exact truth connected with this interesting question.

ENGLISH LIGHT-HOUSES.

From "Illustrated Washington Chronicle."

WITHOUT question the noblest monuments of civilization are those created to promote the happiness and protect the lives of people. It has been justly observed that a government, which guarantees unto its citizens unrestrained freedom, and neglects to provide the safeguards that insure the enjoyment of life, is far inferior to that which, though exercising a proper and even severe firmness in the administration of its laws, uses the means at its command to increase the safety and consequently the prosperity of those it governs.

For proof of this we need but glance at the respective conditions of two different classes of nations. Those which have acknowledged the importance of securing the welfare of their inhabitants by a wise system of public benefits, and the governments which have practically allowed the affairs of the people to take care of themselves.

Of the public benefits referred to there is none greater than that which insures the safety of the mariner—the light-house. Without it commerce would ever remain dwarfed in its proportions; for the perils of the deep, unless lessened by these humane contrivances, would prove too appalling for those hardy enough to brave its mitigated dangers. The countries which have paid the most attention to this important matter are those that have attained the highest position in the commercial scale. It may be asserted that light-houses were constructed by these nations because the safety of their vessels depended upon their existence. But it may be assumed with equal certainty on the other hand that a nation with harbors difficult of access, and unprovided with the warnings necessary for the security of ships in approaching or departing, can never become a great maritime power, for the reason that circumstances combine to prevent its growth in that direction.

This fact has been recognized since the birth of enterprise, although it was reserved for the moderns to bring the light-house system to its present complete and efficient condition. Foremost among the nations that have distinguished themselves in the erection of these valuable assistants to navigation are France, England, Scotland, and the United States. The peculiar conformation of the English coast rendered the construction of many of her light-houses an imperative necessity; without them it would have been impossible to create or preserve after having created, the vast navy of vessels bearing her flag that find their way to and from her ports every day in the year.

The growth of the light-house system of the countries mentioned to its present effectiveness has not been precipitate. It is the result of centuries of patient work, fortified by a continued determination to achieve excellence in this direction.

In this number of the *Chronicle* we give illustrations of a few of the most prominent light-houses of England. We are mainly indebted for the accompanying descriptions to an interesting public document embodying the results of Maj. Elliot's corps of engineers, United States army, tour through Europe, made for the purpose of examining and reporting

upon the light-house systems of foreign nations. At the time of the first appearance of the report we took occasion to refer to it as a document worthy the most careful study on account of the quantity and value of the carefully-prepared information it contained, but as the work is inaccessible to the general public we reproduce such illustrations and extracts as may prove most entertaining. We regret that limited space precludes our copying more extensively, for we seldom come across a public document from which so many and valuable extracts can be made.

The Roman Pharos, now one of the most precious relics of ancient England, is situated within the walls of the Castle of Dover. The antiquity of this monument no doubt exceeds that of any light-house in Great Britain. It has not been used since the Conquest as a warning tower to mariners. From the time of its erection, which was supposed to have been during the reign of the Emperor Claudius, about A. D. 44, up to the period of the invasion by the Conquerors, large fires of wood and coal were maintained upon it. This method was the earliest adopted to guide sailors, and it finally gave way to the reflector, which was in turn supplanted by that triumph of skill, the Fresnel lens. The Pharos is built of brick, of a light red color, about fourteen inches in length and not more than one and a half inches thick, but little more than the thickness of the joints, which are filled with a mortar composed of lime and finely-powdered brick. Its preservation is doubtless owing to the circumstance that the tower was converted into a belfry for the church of St. Mary, and was surrounded by walls of stone, which have nearly succumbed to the action of the elements, and have exposed the old Roman work.

The great electric light at Souter Point, three miles below the mouth of the River Tyne, is a modern scientific triumph. Its location is such as to present serious obstacles to the effective construction of a proper guide to mariners owing to the smoke from the cities and towns on the river, including Newcastle, combining with the frequent fogs, but these have been overcome in a great measure by the introduction of a light which sends over the North Sea its flashes, each of which is equal in intensity to the combined light of *eight hundred thousand candles.* The lenticular apparatus is of the finest possible workmanship, and utilizes every ray of light generated by the electrical machines in the tower.

The Outer Farne or Longstone Light-house, better known to the public as the home of Grace Darling, is situated at the mouth of the Tweed. It is the most northerly of the sea lights of England, on the shore of the North Sea, and is in plain view from the light at St. Alb's Head, the first of the Scottish lights. It is a rock light-house, and its peculiar construction is well illustrated in our engraving. The sea rolls with great violence in the vicinity, and for this reason it was found necessary to surround the tower with high walls to protect it from the encroachments of the waves in time of storm. The daring act of Grace Darling in rescuing nine men from the wrecked vessel Forfarshire, when she struck Hawkin's Reef, must ever throw around this spot a poetic glamor. The house that sheltered heroism of this kind must always be interesting to those who have a sympathetic heart in their bosoms.

The Eddystone Light-house, off the coast of Devonshire, is famous for its great strength. The first light-house on the Eddystone was completed in 1698. Its existence was brief, however, as it was destroyed in a violent storm in 1703. The keepers and the builder lost their lives by the catastrophe. A second light-house was constructed here in 1709, which was destroyed by fire in 1755. The present Eddystone was commenced by John Smeaton in 1756, and completed in 1759. It is a marvel of solidity and strength. The material employed in its construction is stone. The joints are dovetailed, rendering it simply impossible to move one stone without displacing the rest. This has proved the model for all light-houses subsequently erected, except in immaterial details. The science of illumination as applied to the Eddystone was far behind the science of construction, and while Smeaton sprang at once from the prejudice of his time to a full conception of the true principles which should govern the construction of

a work of this character, it remained lighted for many years as at first, by "*twenty-four candles burning at once, five whereof weighed two pounds.*" The quaint expression in italics are extracted from Smeaton's narrative of the building of the Eddystone Light-house. Reflectors were not introduced until early in the present century, and in 1845 these in turn gave way to a second order Fresnellens, the beam from which, with its Douglass burner, is equal to 4,650 candles.

This was the first catadioptric apparatus ever constructed.

The Wolf Rock Light, ten miles from Land's End, was commenced in 1862, and its construction finished in 1869. It is built on a rock two feet below high water. This rock for centuries was the dread of mariners, as in violent weather the sea sweeps completely over it. But since the erection of the staunch house it has been shorn of all its terrors, and that which was once a serious evil is now converted into a positive good, the location and its distance from the land rendering it a most valuable guide for entrance into the English Channel. There is no light-house in existence, however, that has cost more labor than this. The fury of the elements in the neighborhood is such as to render work impossible for long periods. To illustrate this, in constructing a day-beacon on this rock in five years only seventy days were sufficiently calm to permit work. The remainder of the time the weather was too boisterous to allow a stroke of work to be performed. The rock is completely submerged at high water, and is but little larger than the base of the tower, forty-one feet eight inches. The tower is one hundred and sixteen feet high, and solid from the base to the height of thirty-nine feet. The thickness of the walls at the doorway is seven feet nine and a half inches. Four keepers are employed to take charge of the light, and three of these are constantly on duty.

The off man is supposed to spend four weeks on the mainland with his family, but it frequently happens that eight weeks elapse before a landing can be effected. The difficulty of reaching the lighthouse and entering it is graphically described by Major Elliot, who visited it on his tour, and the description carries the conviction that the feat is one attended with no small hazard, as can be well understood from the engraving. The derrick employed for landing, except when in use, is taken down and fastened in deep channels in the rock; otherwise it would be swept away by the sea. The light is an excellent one, and gives out alternate red and white flashes.

The South Stock Light-house, at the extreme westerly point of Holyhead, the extremity of Anglese, is remarkable for the ingenious contrivance which has been adopted to obviate the drawback of its elevated position. A sliding light has been constructed, which is made to ascend or descend, as the exigency demands. By this means when the fog clouds hang over the land and obscure the light of the tower a light is run down to the foot of the cliff, and there gives warning to avoid the dangerous point.

In conclusion we cannot refrain from remarking that France and our own Government have done much to add security to commerce. In fact, the French nation to-day stands practically ahead of either England or the United States. We have merely selected the light-houses mentioned because they are the more striking of those found in Major Elliot's book. We regret, however, that the brevity of the article will not allow us to refer to some of the lights of France and other countries visited by him.

Axle Boxes.—Mr. J. A. Longridge, of Clapham, has patented some improvements in axle boxes for locomotive and other railway vehicles. The invention consists in dispensing with the so-called "rolling brass." Mr. Longridge makes the cheeks or flanges on the axle box in which the axle guides or horns work so as to present two convex surfaces to the axle guides or horns, instead of a parallel groove as hitherto, the narrowest part of the groove being in the centre line of the bearing, and widened out above and below.

—*London Mining Journal.*

ON THE MANUFACTURE OF BESSEMER STEEL IN BELGIUM.*

By M. JULIEN DEBY, C.E., Brussels.

From "Engineering."

The members of the Iron and Steel Institute of Great Britain were the first to promulgate the economic doctrine that it is more to the benefit of the manufacturer and of the trader in general to exchange freely the results of practice and of experience, than to lock up their proceedings from fellow-workers, and to live on hereditary secrets.

I am happy to have it in my power to affirm that this great idea, worthy of the century, is rapidly extending its beneficial influence beyond the contracted limits of the United Kingdom.

In America, Belgium, Germany, and even in France, most workshops of industry are now thrown open to the inspection of competitors, with a generosity which, a few years back, was quite unheard of.

As a slight proof of the truth of the above assertion, I come before you this day with a full statement of what our Bessemer Steel Works, in Belgium, are now doing, and of how they are doing it.

M. E. Sadoine, the able director of the John Cockerill Works, at Seraing, at my request, has given me full leave to divulge to the members of this Institute the whole of the results obtained at his new works, without any restrictions whatever, as to what I may communicate.

I shall, in consequence, proceed, in as few words as possible, to exhibit a condensed summary of the most important facts which I think may interest you.

At Seraing, the iron is most successfully and regularly run direct from the blast furnace into the converters—a most economical process, which, to my knowledge, has not, as yet, been put into practice in Great Britain, but which I believe ought to become universal.

Belgium lays no claim whatever to originality in the matter of this direct process. As early as 1857, the Swedish works had used it, and they continue to do so to this day, adding iron to the charge when the production of the furnace is insufficient. In 1863, the same process was introduced into the Styrian Works, of Turrach, and in 1864, into those of Heft, in Carinthia.*

In 1864, the Neuberg Company, in Styria, applied it also, and this Company, as well as that of Heft, have since that period considerably enlarged their works on the same basis.

In 1867, Terre Noire, in France, employed the direct run from the furnace, and, if I am not mistaken, the Creusot has also lately adopted the same principle.

The new steel works, at Seraing, constitute one of the most important departments of that extensive establishment. Very few in Europe, if any, are better organized at the present time for the economical transformation of iron ore into steel on a large scale.

The whole plant was devised, and the plans put into execution, by the combined efforts of two intelligent young engineers of the company, MM. Greiner and Philippart, to whose kindness I owe to have been able to examine minutely all details, and to have had access to official documents, from whence I have derived most of the figures contained in this paper.

The foundation-stone of the steel works of Seraing was laid in March, 1873, and on the 1st of February, 1874, the first blow was made in the Bessemer converters.

In order to simplify the subject, I shall proceed methodically and follow the ores in their successive transformation:

1. Into pig iron in the blast furnace.
2. Into steel ingots in the Bessemer converters.
3. Into rails, tyres, axles, etc., in the forge.

But, before doing so, I must give a short account of the plant and of its distribution.

* Read before the Iron and Steel Institute.

* These works were fully described as early as 1866, by M. Habets, of Liege, from official documents in the *Revue Universelle des Mines*, vol. xx., p. 273, where the advantages of the process were enumerated.

When the whole works are completed, they will comprise four blast furnaces (of which two are already finished) united by bridges, and between which are placed atmospheric lifts.

Each furnace is furnished with four Whitwell stoves placed in a square, forming thus two parallel rows of eight stoves each.

The principal dimensions of the blast furnaces are as follows:

	Metres.		Feet.
Diameter of hearth......	1.60	=	5.248
" bosh........	5	=	16.40
" top..........	3.50	=	11.48
Total height.............	18.50	=	60
Inclination of boshes.....	$67\frac{1}{2}$ deg.		

Capacity.. 225 cubic metres=7,942 cubic feet.

Three blast engines of the special vertical type of Seraing, so well known on the Continent, and of which 123 are now in operation in various places, furnish the necessary blast, at a pressure which attains 30 centimetres or 12 in. of mercury.

The blowing cylinders of the engines have a diameter of 3 metres, or 9.84 ft., and a stroke of 2.44 metres, or 1 ft. The steam cylinders are on the Woolf condenser principle.

The normal number of revolutions of the engines is 13 per minute. This furnishes 400 cubic metres, or 14,120 cubic feet of blast, the quantity needed for the combustion of 120 metric tons of coke in 24 hours.

To the right and left of the blowing engines are situated the mixing sheds for ore, and outside of these again are the pumping engines for the whole of the hydraulic apparatus of the establishment.

The sheds, where the charges of ore are prepared, are supplied with hydraulic lifts, which raise the ore to the proper height, and allow of its being thrown into separate boxes or compartments, where an intimate mixture of raw material can be easily effected.

In front, and to the north, is placed a group of boilers, made from Bessemer steel plate, 1.60 metres, or 5,248 feet in diameter, and 15 metres, or 49 feet in length. They each carry a large reheater 3.28 feet in diameter, and 49 feet in length below them. The boilers are heated by the escaped gases from the blast furnaces.

On the south side, the blast furnaces are situated alongside the Bessemer foundry, which is divided into three separate compartments by a series of cast-iron columns.

The first compartment comprises the pig bed, and also receives the ladles and the hydraulic lifts, which carry the molten metal from the furnaces to the converters.

The second compartment contains the cupolas, where the re-smelting of the pig iron is effected when at any time or from any cause it is thought advisable to work by the old process.

The third compartment comprises the converter compartment. Here we find six converters, two to each pit, receiving alternately the iron from the furnace or from the cupolas as the case may be, these last being furnished with hot air receivers for keeping the liquid metal hot.

Parallel with these buildings, and on the south side, are situated the blast engines for the converters, the pumps and the accumulators having, to the right and to the left, a group of eight boilers each, of exactly the same make as those employed for the blast furnace engines.

The Bessemer blast engines belong to the class constructed as a specialty by the Seraing Works, and were designed by M. Kraft, the well-known chief-engineer of the Cockerill Company, and whose name must also be honorably attached to the whole mechanical department of the steel works. These engines are of the compound vertical type, realizing a very great economy in fuel. The consumption of coal being only $1\frac{3}{4}$ kilogs., or $2\frac{5}{4}$ lbs., per indicated horse power per hour. We next come to the rolling mill, the length of which is 82 metres, or 270 ft., and which comprises two divisions, each 18 metres, or 59 ft., wide, and united by a row of columns 33 ft. in height.

In the first division are placed six large sized Ponsard and Bicheroux furnaces, whose bottom measures 4.50 by 5 metres, or about 12 ft. by 16 ft., and are sufficient to hold the ingots needed for the two rail mills situated in the next or third compartment.

The first, or blooming mill, has two pair of 30-in. rolls, and is actuated by a reversible engine running 45 turns per

minute by means of gearing. This has a separate engine for the condenser.

The steam cylinders are 32 in. in diameter, and have 4 ft. stroke, the pinions being in proportion of 1 to 2½.

The second or finishing mill, has two housings with 24-in. rolls, and is worked by a direct-acting reversible engine running 80 to 90 revolutions per minute. This engine has two steam cylinders 40 in. in diameter, and acts directly on a crank from 12 in. to 14 in. in diameter, placed on the axis at the end of the combination.

Special condensers are applied to this engine in order to avoid the inevitable counter-pressure so prejudicial to the working of engines of this class. As a complement to the rolling mill, a special rail-finishing shop is established, which will contain all the most modern and improved appliances for the purposes required. All the buildings of the works are simple, light, and airy, iron being largely used in their construction. They constitute a very harmonious and symmetrical whole.

I.—*Blast Furnace Practice.*

As an example of the working of the new plant, we cannot do better than transcribe the results obtained in furnace No. 1, during each week of the months of March and April last. These are as follows:

	Metric tons.			
1875.	Coke.	Ore.	Limestone.	Iron.
March 1 to 7....	417	759	211	370
" 7 " 14 ...	424	771	218	360
" 14 " 21....	415	773	183	369
" 21 " 28....	475	910	184	433
" 28 " Apr. 4	468	913	208	434
April 4 " 11....	459	869	198	449
" 11 " 18....	455	868	172	447
Weekly average ...	445	838	196	409

The mean composition of the charges was as follows:

Coke......	1650 kilogs.	=3630 lbs. Eng. avdp.
Ore.......	3100 "	=6820 " "
Limestone.	725 "	=1595 " "

The ores specially employed were Algerian and Spanish, and the mixture consisted of:

Water............	6.50	
Carbonic acid....... ..	2.50	
Silica.................	15.00	
Alumina..............	4.00	
Lime..................	3.00	
Magnesia..............	1.50	
Oxide of iron..........	64.00	....Iron 45.08
Oxide of manganese...	4.25	.....Mang. 3.00
Sulphur..............	0 10	
Phosphoric acid.......	0.075	
	99.925	

The practical product being 49 per cent. of pig iron.

The proportion of limestone added was 23.50 per cent. The coke was all made in Appolt ovens, and was very regular in quality, leaving from 8 to 10 per cent. of ash.

With the above mixture the iron obtained contained on an average:

Silicon........	2.25
Carbon....................	4.50
Sulphur........	0.04
Phosphorus...............	0.06
Manganese................	3.75
Iron......................	89.40
	100.00

A considerable percentage of slag was produced. This slag is generally of a white color with a greenish tinge, and falls promptly to dust when exposed to the air. Its composition is as follows:

Silica....................	37.00
Alumina..................	13.50
Lime...........	43.00
Magnesia.........	1.50
Oxide of iron..............	0.59
Manganese................	3.50
Sulphur...................	1.25
	100.25

The preceding figures show that the consumption of coke has never exceeded 110 lb. to the 100 lb. of iron produced. This good result is attributable to the great care taken throughout the whole of the metallurgical processes, and to the high heat, 600 deg. Centigrade, maintained in the blast.

It is also interesting to note what becomes of the reduced oxide of manganese which was contained in the charge of mixed ores. Of this, two-thirds are found in the pig iron and one-third go into the slag.

II.—*The Bessemer Foundry.*

The molten metal is, immediately it has run from the blast furnace into the tilt-ladle, taken to the converters by means of hydraulic lifts and the stationary bridge on which it is carried on rails. It is weighed in a very simple manner while on the lift, by means of the indications of an ordinary pressure gauge placed in communication with the water in the hydraulic cylinder of the lift.

No inconvenience is suffered if the iron be left for even one and a half hours in the ladle, beyond the presence of a small solid bottom, which can be remelted afterwards in one of the cupolas.

The whole operation of conversion of iron into steel lasts from 15 to 22 minutes.

In the middle of the decarburation, from 10 to 25 per cent. of rail ends are added, the quantity varying according to the temperature of the bath.

The most remarkable fact connected with the whole process at Seraing is that no spiegel whatever is introduced into the converter at the end of the blow, it having been found that the iron contained sufficient manganese to render this addition quite useless.

As soon as the bands of the spectroscope have all disappeared, the slag is essayed in a very simple and practical manner, the end of the operation being determined simply by a color test. The *modus operandi* is as follows: The blow is momentarily stopped and the converter inclined; a paddle is then introduced through the mouth and dipped into the bath. This is then drawn out, steeped at once in water, and the thin sheet of investing slag taken off and compared to a standard scale.

A lemon yellow slag corresponds to a very hard steel containing:

	0.75 of carbon or more.		
Orange yellow.......	0.60	"	"
Light brown.........	0.45	"	"
Dark brown.	0.30	"	"
Bluish black.........	0.15	"	"

The small metallic globules imbedded in the samples of slag, and resembling blow-pipe beads, may also be tried by hammering them on a small anvil. A very short experience soon teaches the nature of the steel, by the degree of malleability of the globule. If too hard, it requires several blows of the hammer to form a small starred disc, by the splitting of the edges; if too soft, it flattens down at the very first blow of the hammer. These are two extremes to be avoided, unless for quite special purposes.

As soon as the metal in the converter has reached the desired degree of hardness, which, as we have seen, can be regulated at will, by prolonging or shortening the blow, it is run into the moulds in the usual way, and the ingots are taken to the forge as soon as crystallization has taken place, and before they have had time to cool.

Three very light hydraulic cranes to each pit lift out the ingots rapidly, and without any kind of difficulty. The pit itself is very wide, 10 metres, or 33 ft., in diameter, and is very shallow, only 0.90 metres, or 3 ft., deep, and the moulds being placed side by side, plenty of space is left for circulation in the centre.

The general distribution of the Bessemer foundry brings to mind the American works, and nowhere on the Continent, nor in England, does there exist any establishment where the practical facilities are greater, nor their results more economical, than they are here. Having visited nearly every steel-work in Europe, and many in America, I can speak with confidence in this respect.

At present, the production reaches 100 tons of ingots for each pair of 6-ton converters in 24 hours, but this figure will be largely increased when the new rail mills are finished, and rails of two or three lengths are rolled at once.

The economy realized by the direct run from the blast furnace is easy of calculation. It consists in a reduction in the quantity of iron used, added to a saving in fuel, and to a diminution in labor.

Since iron has been run from the new Seraing blast furnaces, not a single case of black slag has occurred, which gives sufficient proof that the iron produced is fit for the manufacturer of first-class steel.

A very remarkable fact, as yet quite unexplained, is the undeniable one, that the direct product of the blast furnace works better in the mill and gives much tougher steel than that obtained by the

resmelting of the same iron in the cupola.

The chemical composition being identical, the steel from the direct process has stood the ordinary tests for rails and tyres much better than that which has been obtained from the cupolas.

III.—*The Rail Mill.*

Until the present day, the ingots have been taken to the old rail mill, and rolled into single length rails. Even here, the advantages and economy of rolling the ingot while still hot have been fully appreciated. A very ordinary mill produces, in this case, 600 tons of 20 ft. rails, weighing above 70 lb. to the yard, per week.

No doubt whatever can be entertained that the new mill, now in course of erection, and which will work ingots two or three times heavier than at present, will turn out 1,200 tons per week without any difficulty.

As it takes 30 hours for the conversion of iron ore in the blast furnace into pig iron, and as the operation in the converter lasts about one hour, including carriage of ingots, handling, etc., and assuming that after one hour of heating the rail may be rolled; we confidently affirm that, in the short space of 36 hours after the arrival of the ore at the works, a rail may be ready for shipment, and during the whole process the material will not have been allowed to get cool.

This appears to me about as complete a solution of the problem of producing steel direct from the ore as has yet been proposed by many of the ingenious searchers of the day.

WATER SUPPLY AND DRAINAGE.*

By W. A. CORFIELD, Esq., M.A., M.D.

I.

It will be our purpose in this course to discuss, in the first place, the sources and the kind of water that are required for large communities—the kind in the first place, the quantity in the next, the places to get it in the third, and then the ways to convey it to the community.

It is only one part of the fuel of a community that we have to consider. We shall then consider what are the wastes from a large community, and whether, although useless for the purpose for which the original fuel was supplied, they can be made useful for other purposes, and if so, how? Whether again there is any necessity of getting rid of them, and if so, how this can be done most effectually, and most cheaply, and without prejudice to other communities.

Now then as regards water. Water is required in a large community for a great variety of uses. These uses were divided by the Romans, and they have been divided ever since, into public and private uses. The public uses are such as for cleaning streets, extinguishing fires, for fountains, for public baths, and so on. The private uses are for drinking, washing, cooking, etc. Thus water you see at once from the mere examination of its uses comes to the community to be soiled. It comes in order that the community may be supplied with one of the necessities of life. It comes to wash communities, places, and habitations. It comes, I repeat, to be soiled. It is, therefore, generally, when soiled, useless for the purpose it was originally wanted for. It has either to be purified or got rid of. A community requires pure water for some purposes, and those are especially for drinking and cooking. Pure water—I do not mean chemically pure, but we shall see directly what is meant hygienically by pure water—is not necessary for every purpose such as for washing the streets, extinguishing fires, etc. However, practically speaking, only one kind of water can as a rule be supplied to a community, and so it becomes necessary for us to know where we can

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get this sufficient supply of water of a certain quality, viz., sufficiently good for drinking.

Now, roughly speaking, a drinking water should be, in the first place, transparent. In the second place, it should be transparent to white light: that is to say, it should be transparent and without color. It must be without taste and without smell, and it must deposit no sediment on standing, and have no particles suspended in it. Those are the rough qualities of water which anybody can examine for himself; the best way to look at it is to look through about a foot or 18 inches of it in a long glass cylinder, placed on a piece of white paper. It must be aerated to be fit for drinking, and cool. Now, if the water you are examining does not fulfil these conditions, it must be rejected at once, or brought to satisfy them. We have to consider how these conditions are to be fulfilled, and we ought to satisfy them on a large scale. But a water may comply with all these conditions, and yet not be a safe water to drink. It may contain substances which you cannot tell in any of these ways, and practically speaking, all waters do. Substances whether in solution or suspension may be hurtful, or they may be harmless, and now I want to tell you how, if you have a chemical analysis of a sample of water before you, you can tell whether that water is suitable for your purpose or not. That is a thing you do not generally find in engineering books. It is necessary for you to know it, because if a report is brought up upon a particular water, you ought to be able to know whether that will be a satisfactory water or not.

Natural waters contain dissolved (in the first place especially) carbonic acid gas. They contain all the constituents of air in solution, but the gases are not in the proportion in which they are in atmospheric air. There is often a great quantity of carbonic acid gas, and oxygen being more soluble than nitrogen is generally in larger proportion than in atmospheric air. Now the carbonic acid gas is the one that I am going to speak of first. Water containing carbonic acid in solution has the property of holding in solution quantities of certain salts that it would not dissolve otherwise, or only in much smaller quantities, and the chief of these is carbonate of lime. Natural waters often contain then, in the first place, salts of lime, especially the carbonate, dissolved in carbonic acid. They contain often the sulphates of lime, soda, magnesia, iron, and so on—in fact, different salts of these and other bases. Phosphates they all contain, and also chlorides and nitrates. All natural waters contain the latter in certain proportions—even rain water. Almost all of them contain salts of ammonia. The question arises which of these may be allowed in water, and which may not, or which, at any rate, may not be allowed above a certain quantity, and what is the quantity? Beyond those simple characters for pure water which I gave you a few minutes ago, there is a property of natural waters which can be easily ascertained by any one, and which constitutes one of the best known differences between various specimens of water, and that is the quality of hardness. What does that mean? Hardness is tested in this way. Pure water dissolves soap, which is a combination of soda with some of the fatty acids. Pure water dissolves soap perfectly and forms a lather at once. Now water containing certain salts in solution, and notably salts of lime, magnesia, and iron, does not do so, because these salts form insoluble precipitates with the soap. That is what is meant by the water being hard. If a water, instead of lathering with soap immediately, takes a great deal of trouble to make a lather, does not do it till after some time, and causes a curdy precipitate, then it is a hard water. That is, of course, a very rough way of putting it; but the amount of soap that is required before a water will lather, gives a test of the amount of salts which cause the hardness of the water, and the chemist takes a standard solution of soap and tries how much of this solution is required before he can get a lather with water, and he says that the water has so many degrees of hardness. What is meant by a degree of hardness? That each gallon of the water contains in solution an amount of salts which will precipitate as much soap as a grain of carbonate of lime would precipitate. What is the importance of this? Hard water is as a general rule less wholesome than soft, and often much less so, it is not so

good for household purposes, nor for use in engines, and it entails an enormous waste of soap. It is therefore objectionable, even if the hardness is caused by the presence of harmless salts. The total amount of hardness, the degree of hardness of a water before anything is done to it, is called the "total hardness," and if the total hardness of a water is greater than six degrees on what is called "Clark's Scale" (the value of a degree of which I have already explained) it is called a hard water; if less, it is known as a soft water. Now hard water (supposing you have only got hard water, and cannot get a supply of soft water) is made softer, in the first place, by boiling. That can be done on a small scale. If you boil hard water, of course the carbonic acid is driven off, and the salts held in solution by it, especially carbonate of lime, are precipitated. There is another way of rendering hard water soft, and this can be applied on a large scale; it is known as "Clark's process." The carbonate of lime is held in solution in the water by carbonic acid; you can precipitate it by boiling, or prevent its being held in solution by causing the carbonic acid to combine with something else, as with more lime, and Clark's process which is now used on an extensive scale (and ought to be used very much more than it is) consists in adding to the hard water milk of lime. This milk of lime combines with the excess of carbonic acid, forming carbonate of lime, which falls down as precipitate together with the carbonate of lime that was previously held in solution, thus leaving the water softer. If you boil water, and then determine the hardness that remains, that is called the "permanent hardness;" an extremely important matter. The importance of it consists in this, that it cannot be removed at any rate on a large scale, and, in the second place, that it is due to salts several of which are injurious, so that a large degree of permanent hardness indicates a bad water. Now this permanent hardness (the hardness that is lost by boiling is called "temporary hardness") is due chiefly to the sulphate of lime and chloride of calcium, and to magnesian salts. These are all objectionable in a water. Let me give you some examples of degrees of hardness of various specimens of water so as to give you a definite idea of hardness.

The hardness of the Thames water above London is 14 degrees of Clark's scale. That is a hard water. The hardness of the New River water is 15½ degrees. That, too, is a hard water. The water of Bala Lake has only ¼ of a degree of hardness, and of course that is an exceedingly soft water. I must tell you before going on (because it is very likely that you may take up one of the Registrar General's Reports and see what he says about the water supply to London) that it is now very usual to express hardness in another way. That is to say, instead of saying so many grains per gallon as is done in Clark's scale, hardness is now very generally expressed by parts in 100,000, and I mention this at once, because the results of most of the analyses that we shall have to refer to during the lectures are given in parts per 100,000. Of course, if you are given the hardness of water in parts per 100,000, you can convert it into degrees of hardness in Clark's scale by multiplying by seven and dividing by ten, because Clark's scale gives the results in grains per gallon; a grain per gallon is one part in 70,000. On this new scale, as an example, the hardness for the last week of last year of the five Thames companies was about 20 degrees, that is to say, about 14 degrees by Clark's scale.

The hardness, again, of the water supply which is derived from deep borings in the chalk was 29.4 on this scale, or 20.58 of Clark's scale. Of course that is a very hard water indeed. But the hardness of these two waters is quite different, because the permanent hardness of Kent water is very little indeed. The total hardness of that water is almost entirely due to the carbonate of lime, whereas, much of the hardness of the water supply to London by the Thames companies is due to salts other than carbonates, especially to sulphates. Therefore, you get much information about the quality of water by its hardness. If you know water has a high degree of permanent hardness, you know it has a very good chance of being a bad water. It contains probably sulphate of lime and chloride of calcium, and perhaps magnesian salts. The latter are

especially objectionable to water, and any water which gives even a small amount of salts of magnesia is to be rejected. Water containing these salts causes diarrhœa when drunk, and it appears to be from the presence of these salts in drinking waters that the swelling of the neck known as *goitre* is produced in Switzerland and other countries.

The next thing to which I wish to draw your attention with regard to substances dissolved in water, is, the amount of chlorides that may be present. I may say broadly, that if you see in a report on the quality of a water that it contains much chlorine, or much common salt (chloride of sodium), you may at once put it down as a suspicious water, and you will see why in a minute. Where do you get chlorides in a water? They may come from an infiltration from the sea. They may come again from strata containing a quantity of common salt. But another source of chlorides in a water is pollution by sewage. All sewage contains a considerable proportion of common salt. This is one of the necessities of life, it is contained in many of our foods, and in excretal matters, especially in the urine, and so sewage contains it. The average amount in the sewage of water-closeted towns is ten parts of chlorine in the 100,000. Pure natural waters contain less than a grain of chlorine in a gallon, or about 1 part in 100,000. So, if in a sample of water for which you get the analysis sent, you see more than a grain in a gallon of chlorides, you must at once know the reason why. London drinking water contains 2 parts in 100,000. That is not very bad water, and as it is got from the Thames we know that it has been polluted by sewage. The water derived from the chalk—the Kent water—actually contains more than that, but we have a very good reason for not objecting to it on that account, inasmuch as we know that it is not rendered impure by sewage. The well waters of London mostly contain more chlorine than sewage, they are in fact, a concentrated form of sewage which has gone through certain alterations. I am not here alluding to the Artesian Wells, but only to those which are supplied by the subsoil water above the London clay. The amount of chlorine is a very good test of the purity of a water, except that you must always allow for the possibility of chlorides being present in the soil through which that water has gone.

Nitrates and nitrites are given you in the Registrar General's Reports as the test for what is called "*previous sewage contamination.*" What does that mean? It means that the nitrates, &c., that are dissolved in water come in a great majority of cases (if not in all) from the oxydation of organic matter at some time or other, or in some place. Now to show you how plain it is that water must not be rejected merely because it contains nitrates, I must tell you that there are nitrates and nitrites in all waters, even in small quantities in rain water. What amount of nitrates may be found in water without giving a suspicion of previous contamination? Allowing that they are not injurious in themselves, yet, inasmuch as they at once make you suspect that the water containing them in solution has, at some time or other, been contaminated with organic matters to a large extent, which organic matters have been oxydized, the result being the production of nitrates and nitrites; inasmuch as that is the case, if you get much nitrates, &c., represented in a water, you must at once see if that water is derived from a source where it is likely to get contaminated with refuse matters; because if it is, although the nitrates are harmless, and although it is very desirable that these matters should be oxydized to that state, still you are always liable to its happening some day that the water is contaminated by the solution of these organic matters in their crude unoxydized form, in which case they are very often, if not always dangerous. Let us see what amount of nitrates is found in various waters. In the drinking water we get in London from the Thames there are about 2 parts in a million (or 0.2 in 100,000). In the New River Water (North London water) a little more than 3 parts; and in the Kent water 4 parts in a million, so that the deep chalk waters (which we know must be very pure) contain more nitrates than the others do, a sufficient proof that the presence of nitrates is not of itself a sufficient reason for rejecting a water. The waters from the Cumberland Lakes contain very much less. To

give you an example of a water containing a great deal, I may cite the instance of a well at Liverpool which was found to contain more than 8 parts in 100,000 of nitrates and nitrites, which were all derived (or in all probability derived) from the oxydation of sewage that had traversed the ground round that well. If nitrates be present in large quantities it must be regarded as a suspicious circumstance, unless you have good reason to know that the water comes from a source which is beyond the suspicion of contamination. There are quantities of nitrates in many soils. The presence of nitrates in water got from such soils would not justify you in having the water condemned as a source of supply if there were no other reason.

Salts of ammonia. These, too, are contained in natural waters in exceedingly small quantities. They do no particular harm in themselves, but they frequently come directly from sewage. The numbers in a drinking water representing salts of ammonia ought to be in the third place of decimals for parts in 100,000, or if in the second place of decimals ought to be small. Now the water supply of London, filtered Thames water, contains .001 to .005 parts in 100,000. That is pretty good. The water at Bala Lake contains .001 parts, and rain water contains the same amount; so that we may expect salts of ammonia to be contained in all natural waters. Sewage contains about 6 parts in 100,000. Well water often contains large quantities, four parts for instance; the pump water in London contains nearly one part in 100,000, and the water of the Thames at London Bridge 0.1 part in 100,000; these are all bad waters, so that when you see ammonia mentioned in an analysis of water in greater quantity than is represented on the second place of decimals in parts per 100,000, you may always safely condemn it, for on looking further you will find what I am now going to speak of, namely, organic matters.

Now the actual organic matters present in a water may be in suspension or solution. If there are organic matters in suspension a water may be safely condemned, because they may even by agitation pass into solution, and so the fact of your trying to separate them may cause more of them to get into solution. Organic matters you will find in analysis represented in two different ways. In one, as for instance in the analysis given by the Registrar General, you will find organic matters represented in this way: so much organic carbon, and so much organic nitrogen in the 100,000, and the Rivers Pollution Commissioners have given this as a standard, not of drinking water, but of a water that shall be considered to pollute any water course to which it is turned. Two parts of organic carbon in 100,000 or 3 parts of organic nitrogen in 100,000. What does the London drinking water contain again? From 3 to 4 in 100,000 of organic carbon (I take this from the Registrar General's reports), and about .05 of organic nitrogen. Now we shall see at once the difference between drinking water derived from such a source as the Thames and filtered, and drinking water derived by boring into deep strata—into the chalk. The chalk water only contains .06, that is the fifth of the quantity of organic carbon, and .01, a fifth of the quantity of organic nitrogen that the water supplied by the Thames Companies contains; so that when you come to organic matters, you see the difference at once between a water that is derived from a pure source, and one from an impure. The other method that I have to mention to you, which is used for expressing the amount of organic matters in water, is called "Wanklyn's method" from the chemist who discovered it. This method consists in the conversion of the nitrogen contained in the organic matter in the water, or a considerable part of it, into ammonia, and then it is estimated as so much ammonia. I dare say you all know that the test that chemists have for ammonia is perhaps the most delicate test with which we are acquainted. This ammonia you will see mentioned in the records of analysis as "albuminoid ammonia," and to a certain extent it does represent the amount of organic matter in the water. This albuminoid ammonia in a drinking water must not be allowed to be above the third place of decimals. If it appears higher than the third place of decimals in parts of 100,000, if in the second place, or if in the first, it is bad. If in the first place it is decidedly bad water, and contains a considerable amount of organic

matter in a state of solution. You may consider that the albuminoid ammonia represents about ten times its weight of dry organic matter, and about forty times its weight of moist organic matter. So that .05 of albuminoid ammonia in 100,000 represents about 2 parts of moist organic matter in the water. You see that when you have an analysis of water before you, you must consider the different things together. The nitrates help to condemn a water with much organic matter in it. The ammonia does the same, and the chlorides especially so, and chlorides are to be regarded as a suspicious indication in water, if you have not good reason to suppose that they come from some other source than the one I have indicated. The danger of organic matter in drinking water consists in this fact (of course organic matters are necessary to us for our food, and it is not the mere fact of its being organic matter that renders it dangerous) that it is organic matter in a state of rapid change; in a state of putrefactive change, and then that it may contain, and often does contain (especially if it is derived from excremental matter) the poison of specific diseases, which may be distributed in the drinking water to a population and cause an outbreak of cholera, typhoid fever, etc. We know now what sort of water must be got for drinking. The above are its characteristics, and the water supply must either comply with these conditions, or be made to do so artificially.

Now how much of it is wanted? You can look at this in two ways. You can get to know by experience how much bodies of men and towns always have wanted. The amount, of course, varies immensely with the use of baths, whether they are public baths or not, with the amount used for washing the streets, and for manufactures, and also with the amount of waste, because that is a very important item. Now, for washing, drinking, and domestic purposes generally, you may put it down (if there is reasonable amount of bathing) at about ten gallons a head a day, and then you must add nine or ten more for flushing the sewers and washing the streets. Much of this will be added through the water-closets. Thus you may say 20 gallons a day without waste may be taken as a kind of average. For trades you must allow 10 gallons more as a rule. If there are public baths, and where there are many animals, as horses, which require about 12 or 15 gallons a head for washing and drinking, you must make a greater allowance. You will see that about 30 gallons a head a day is the least even where there is no extra demand, and that is about the amount provided in London, and that is about the least that you should aim at. Professor Rankine tells you that 35 gallons is the greatest amount necessary. However, they don't think so everywhere. New York manages to get through 300 gallons, and does not find it too much. In ancient Rome (to show you that these matters have been thought of a long time ago) they had nine aqueducts to bring water to the city. They thought it of so much importance that several of these aqueducts were from 42 to 49 miles long, and one of them, the Marcian, was 54 miles long. Frontinus, who was the superintendent, and who wrote a most excellent work about them, giving accurate descriptions and measurements of them, tells us the two most recent were made because the seven already in existence "seemed scarcely sufficient for public purposes and private amusements." Now the sectional area of the water supply to Rome by these aqueducts was 1120 square feet, and it is pretty sure that there were not more than 332,000,000 gallons daily brought to Rome by them. I suppose there were not more than a million people; that gives you about 332 gallons a day that they found necessary.—(Mr. James Parker on the "Water Supply of Rome.")

Now, let me give you one or two points about the measurement of water that you will find useful. The measurement of water you will often find given in cubic metres. A cubic metre is 35⅓ cubic feet or 220 gallons. That is to say, a cubic metre of water is 220 gallons, and as a ton of water contains 224 gallons, a cubic metre of water is almost exactly equal to a ton by weight (or tun by measure). A cubic foot is rather more than 6 gallons, and 100 gallons are just about 16 cubic feet. Let me just give you an example of this. London during December, 1872 (I find from

the Registrar General's report), was supplied daily with 100 millions, nine hundred thousand, and something odd, gallons of water. That is to say 458,577 cubic metres, or about the same amount of *tons* by weight or *tuns* by measure; that is, 201.8 gallons to each house, or rather less than a cubic metre to each house, and 28.4 gallons to each person. I told you it was 30. Well it varies a little. It is a little under 30 very often. Of the total amount of water supplied to a place, you may take it as a general rule that 80 or 82 per cent. is required for domestic purposes, so that during that month of December in London, there were about 23⅓ gallons used for domestic purposes. Hence the conclusion about the quantity is, that the least you must endeavor to get is 30 gallons a head a day without any very extra demands. Of this about 80 per cent. will be required for domestic and the rest for public purposes.

So much for the quality of drinking water, and the quanty to be supplied. We have now to go on to consider the places where water of this quality and in sufficient quantity can be procured. The main sources of water are rain, and the sources that are subordinate to rainfall—wells, springs, streams and rivers. Some other sources which are used occasionally, and which are of very little use for a great supply, are such as the dew, ice, snow and distilled water. These latter we may dismiss with a word or two as only of exceptional utility. Dew has been used in deserts and at sea. Ice and snow furnish enormous quantities of water in certain places where they abound. Ice furnishes an exceptionally pure water, because in freezing the salts are separated out, and the gases too; such water therefore requires aeration. Snow and ice if used should not be collected near to dwellings, because of the risk of contamination. Distilled water is an important water supply now, especially at sea. Its chief fault is that it requires aeration. To give it this Normandy's apparatus may be used, or it may be allowed to fall from one vessel to another like a shower. It has been said that cases of lead poisoning have occurred at sea "partly from the use of *minium* in the apparatus, and partly from the use of *zinc pipes* containing lead in their composition," (Dr. Parkes.) So much for the subordinate sources, which are all of little importance to us.

We now come to rain, which is the original source of all great supplies. Rain, which we are going to consider, is, of course, caused by the fact that when two air currents come together, both saturated with moisture one having a lower temperature than another, the mixed air, though it has a mean temperature, has not the mean capacity for water, but a capacity less than the mean, and so some of it falls as rain. Is rain, as it falls, sufficiently pure to be used as a source of drinking water? In the first place it is very soft. In the second place it is well aerated. It dissolves especially carbonic acid and oxygen from the air—the former being about three per cent. of the total dissolved gases, and the latter from 30 to 40 per cent. It contains nitrates and nitrites, especially during thunderstorms. It contains salts of ammonia, which render it more alkaline when collected in the country. Near towns it contains most of the impurities that are found in the air of towns, and especially it becomes acid instead of alkaline, absorbing a large amount of the sulphuric acid that is in the air. It contains organic matter, and this in increased amount near towns. Rain half a mile from the extreme south-west of Manchester, although the wind was blowing from the west, tasted flat, insipid, oily and nauseous—deposited organic matters, and even organized bodies in considerable quantities, and left a clear water above, containing more than two grains of organic matter in the gallon. Dr. Angus Smith, who examined this water, makes the following remarks: "It becomes clear from the experiments that rain-water in town districts, even a few miles distant from a town, is not a pure water for drinking; and that if it could be got direct from the clouds in large quantities, we must still resort to collecting it on the ground in order to get it pure. The impurities of rain are completely removed by filtration through the soil; when that is done, there is no more nauseous taste of oil or of soot, and it becomes perfectly transparent." He is therefore of opinion, that rain collected directly from the air cannot, at any rate near to towns, afford a proper

water supply. However, since rain is the source of all the supplies that we get, it becomes necessary and of great importance in estimating the amount of water that can be got in a district to measure the rain-fall of that district. Now the depth of the rain-fall of a district has extraordinary varieties, both as to place and time. For instance, as regards time, the tropical rain-fall is almost all at one part of the year. With us it is variable. The rain-fall is measured in England by its depth in inches. The rain-fall is greater in mountainous districts, and on the leeward side of mountains, if they are not high enough to penetrate the clouds, but if they are, it is on the windward side, because the clouds do not get over the tops of the mountains. Now, for the supply of water, the important points to be known about the rain-fall are these. The first is the least amount of rain that has ever been known to fall in a year in a district; the minimum annual fall. Then it is important to know the distribution of the rain throughout the year, and especially the longest drought, because you have got to provide for that time as well as for any other time, and the observations on the rain-fall of a district should extend over not less than 20 years. Of course it is not often that you can get observations at any locality that have been maintained for 20 years, and so we shall have to consider in an instant or two how we are to get over that difficulty.

The machine used for measuring the depth of rain-fall is called a rain gauge. It is essentially a funnel, the area of the top of which is known very accurately. The top of this funnel is provided with a vertical rim to catch the splashings so that none may be lost. Below the funnel there is a glass vessel placed to receive the water. The height of the water in it may be indicated by a float, or its quantity may be ascertained at given intervals of time by measuring or weighing it, and that is the best plan. Of course the number of cubic inches of water, which is the same as the number of square inches of the area of the funnel, gives you one inch of rain over that area. Suppose the area of your funnel it 20 square inches, 20 cubic inches of water will obviously be the result of one inch of rain-fall over that 20 inches. It is most convenient to measure the water, and the measuring glass is constructed in the following way:—At the place where that amount of cubic inches of water stands which is equal to the number of square inches in the area of your funnel a line is drawn, and this represents one inch of rain-fall. If the area of your funnel is 20 square inches, then you take 20 cubic inches of water which you have weighed or measured accurately, place it in your glass vessel and mark *one* at the level where it stands, because that amount is equal to a depth of one inch of water over the area you are observing One cubic inch of water weighs 252½ grains, almost exactly. That one inch is divided into tenths and hundreds; and with this vessel you are able to measure the amount of rain that has fallen through the funnel in a given time. The top of the gauge must be placed nearly level with the ground; the instrument must, in fact, be sunk. It must be placed in an open situation, and a fence put round it if necessary. One is very frequently placed at a height above the ground, and one on the ground to show the difference in the amount of rain that falls at the two levels. The amount of rain that falls at the level of the ground (leaving hills out of the question) is always greater than the amount that falls at any height above the ground. If you have got records of the rain-fall of a district for a considerable number of years your work is to a great extent done, because then you have merely to take out the facts that you want. If you have not, the only way to do it (with a limited time) is to place rain gauges at convenient situations, and as many as possible all over the district you are examining, and if there are any hills in or near the district some of them ought to be placed on their tops, and each of these rain gauges ought to be carefully and regularly examined at certain fixed times. Then you must compare the records of all these gauges with the results given by the nearest rain gauge that has been observed for a considerable number of years, to get a kind of relation between the rain that falls at these different stations on your district, and the rain that falls at the nearest place from which you can get any re-

liable data, and from this comparison you must calculate what will probably be the longest drought in your district, and what is probably the least annual rain-fall. Now, the average in different parts of England is from 22 inches to 100, or even 120 per annum ; in some countries, as Burmah, 180 to 220, and it is even said to be as much as 600 inches in one place. This useful rule was given by Mr. Hawkesley (and certainly the tables show that it is a very accurate rule) that if you take the average rain-fall of a place for 20 years. and substract a sixth from it, that will give you the average annual rain-fall of the three driest years during that period. If you take the average annual rain-fall for 20 years, and take a third part from it, that will give you the amount of rain in the driest year of these 20 almost exactly, and if you take the average of 20 years, and add a third to it, then that will give you pretty nearly the amount of rain in the wettest year.

So you get with a considerable amount of accuracy the quantity of rain ; the least amount of rain you are likely to get, and the greatest as well. Then, of course, you want to know the area of the district, and besides the actual amount of the rain-fall, you must also know the amount which is available. In the first place, a great deal of the rain-fall is lost by evaporation and absorption. Evaporation from the surface, and absorption by plants, &c. Then, if the ground is very porous to a great depth, a considerable amount will be sbsorbed so fast that you cannot collect it. Most of the rain-fall is at once available from or near the surface in steep countries, and especially those which are formed of primitive and metamorphic rocks, as granite, clay-slate, &c., and generally from impervious rocks that are steep-sided. Almost all the rain-fall in these cases is available at once. It runs off the surface and collects in lakes, and is available directly. And then, on hilly pasture lands in limestone and sandstone regions, something like two-thirds of the rain may be considered available, and on flat pasture countries something like one-half. For instance, on the green sand, Mr. Prestwich estimated that from 36 to 60 per cent. is available. On chalk and loose sand there is very little indeed available.

Now one of the most important things, if *not* the most important thing to know, is the geological character of the rocks of the district you are examining, because that will tell you a very great deal about the amount of available water, and about the way to get it. We are told that in chalk countries the rivers and streams carry off at once about a fifth of the rain-fall ; that the evaporation and absorption by vegetables and animals amounts to as much as a third, and that the remainder (*i.e.*, the greater part of the total rain-fall) sinks into the ground. In less absorbent strata you may put down that it is about equally divided—that one-third is carried off by the streams, &c.; another third absorbed by plants and animals, or lost by evaporation, while a third sinks into the ground.

Well now, let us consider what means have been taken to get at this water that sinks into the ground. Of course it is got at by digging down, and now we must consider in what strata we are likely to be successful in digging wells or making borings to get underground water. In the first place, wells in sands lying over impervious strata, over clays especially, if they are not deep, do not, as a rule, afford much water. They may, however, afford a fair supply as to quantity, but very often afford a bad supply as to quality. For instance, the wells sunk into the sands and gravels over the London clays afford a very impure water. If water of this description has come directly from the surface, and especially in the neighborhood of towns, it is contaminated in all sorts of ways. The water in these wells never overflows or spouts up. Wells, on the other hand, sunk through impervious strata to pervious ones below, generally, though not always, supply excellent water. At any rate, they have much greater chance of supplying excellent water, because they supply the water that has come from the high grounds at a considerable distance. For instance, the borings that are made through the London clay down to the chalk, supply some of the best water in London. The Kent water is still better, and is supplied in large quantities by borings which pass through the chalk, through the upper green sand, and through the gault (an impervious stratum)

into the lower green-sand. These wells are known as Artesian wells. The water rises up a considerable height in them, and may overflow. It is often thought that Artesian wells always overflow, but they don't. The water rises up to a certain height, which height is of course determined by several considerations,—for instance, by the height it came from originally. Of course the water that you get from under Kent is the water that has fallen upon the outcrop of the green sand at a very considerable distance round the London basin.

Mr. Prestwich, who has paid the greatest attention to the water supply of London, and to the arrangement of the strata around London, has calculated that, from the lower green-sand underneath the London basin, there is to be got an enormous supply of water for the metropolis, that is to say, on the presumption that this lower green-sand is continuous underneath London. It would not be fair if I did not tell you here that the lower green sand does not appear to be continuous underneath the London basin. Some of the older strata are brought into contact with the chalk, so that the lower green-sand is missing, probably, underneath a great part of the district. This we know from deep borings which have been made at several places. Of course the chalk and also the green-sand are merely instances. You want to know the alternation of the strata right away down the whole geological series, so as to be able to say, if you go into a country and study the maps and sections for a short time, "If we make a well here and bore down, we shall probably go through a band of clay into a pervious stratum, and get a supply of water." You want for this purpose to study the geological maps, and to have ample time to do it. If we go below the chalk into the oolitic series, we have similar alternations of pervious and impervious strata. When we go below this we come to the new red sandstone, and I mention this, because there is an important point connected with it. The new red sandstone is (to a great extent) a pervious stratum. It contains enormous quantities of water, but the caution about it is, that in many countries it holds immense salt deposits. It is in the new red sandstone of Worcestershire (for instance) that the salt deposits of Droitwich are found; so that borings in the new red sandstone (although it is true that some towns are supplied from that stratum), are frequently found to give a brackish water. Below this come the Permian strata, in which you have the magnesian rocks, that I mentioned last time, and it is a mischievous thing to bore into these strata, because you may get water containing large amounts of magnesian salts. Towns which are placed upon these strata are best supplied (like Manchester) from older formations, such as mountain limestone, and so on, which generally afford excellent water. The best supplies are obtained from them, not by boring or by wells, but from springs. There is one thing I must mention, before I leave the wells, and that is, that the sinking of deep wells may lower the level of the water in the country above considerably, and that is a point that has often to be taken into consideration. For instance, Mr. Clutterbuck showed that wells at a considerable distance from London have been seriously affected by the pumping of the green-sand water below London. He showed that the level of the water in these wells was affected so much, that you could tell by the levels of the well waters at a considerable distance from London, whether the pumping had been going on in London on the previous day or not. There is another thing that requires to be known, especially about borings in the chalk, and that is, that some of the borings will give an inexhaustible supply of water, practically speaking, while borings close by will give you next to none. This Mr. Prestwich accounts for, by stating that the water in chalk runs chiefly through crevices, and does not infiltrate through the mass of rock. Before I say a few words to you about the construction of wells, I have something to say about springs, and the amount of water they supply. Now springs occur where you have an impervious stratum cropping out from beneath a pervious one, and this may happen in various ways.

The water in springs, and also that in wells, varies very much in quality according to the place that it is taken from. Spring water differs from rain water in that it has passed through certain rocks,

and dissolved more or less considerable quantities of substances on its way. Spring water resembles rain water in containing a considerable amount of carbonic acid in solution. This has the property of dissolving many substances, one of the chief of which is the carbonate of lime. The water then passing through the rocks dissolves carbonate and sulphate of lime, salts of iron, &c. It is important to know this for many reasons. In the first place, some of these waters dissolve, in mountain limestone districts for instance, so much carbonate of lime as to become what is known as petrifying springs. Of course if you take a petrifying spring and bring it along an acqueduct, under certain conditions your supply is stopped up: and one of the acqueducts at Rome is to be seen to this day perfectly closed for a considerable length with a deposit of carbonate of lime and other salts, because the contractor took in a spring that he was not told to tap—a mineral spring. Now the purest spring water you can get comes from the igneous, the metamorphic, and the older stratified rocks. Many of these hard rocks yield a very pure water without a great deal of salts in solution. The mountain limestone, the oolitic limestones, and the chalk rocks also yield a good supply, and these waters are fit for drinking so long as they do not contain any quantity of magnesian salts. Water from sandstones, especially the new red sandstone, I have told you, often contains common salt. Waters in clay countries very often contain considerable quantities of the sulphate of lime. The waters of the London and Oxford clays do, as also the water of the lower lias clay. These are bad waters. They are permanently hard and unwholesome. Well waters have partly the same qualities, unless they contain additional impurities from the causes I have mentioned before. River water is often purer than spring water; that is to say, it often contains less total solids in solution. The permanent hardness is generally greater. It contains less substances in solution, because much of the carbonic acid has escaped, and the substances it held in solution have been deposited. River water very often contains much more organic matter, especially near towns.

Wells sunk in hard rocks may require no lining at all; if they pass through sandy strata they require a lining of brickwork, and sometimes part or the whole of it must be set in cement. For an artesian well, an ordinary well is dug first of a tolerable breadth and depth, and then a boring is made which varies from twenty down to three or four inches in depth. As soon as an impervious layer is bored through, and a pervious stratum reached, the water rises through the boring into the well (which acts as a sort of cistern), and has to be pumped up, or it may rise so high as to overflow.

The ordinary atmospheric lifting pump is seldom used, but a kind of lifting pump with a solid piston and metallic valves is often used. In fact, the cylinder in which the solid piston slides is connected with the space between the valves above the piston instead of below it. So that when the piston is raised the water is lifted through the upper valve, and when it is depressed water is drawn from the well into the body of the pump through the lower valve. Forcing pumps are also used. They are driven by engines, and the water is pumped into air vessels, by which the pressure on the mains is equalized so that it does not come in jerks. Let me mention one or two examples of artesian wells, and the amounts of water got from them in different strata. From the well of Grenelle, near Paris, in 1860, there were about 200,000 gallons daily. This well when first sunk yielded 800,000 gallons daily, so that you see the supply has considerably diminished with time, which is an important thing to take note of. The boring of this well of Grenelle began at twenty inches in width, and ends at about eight or somewhat less. It is 1,800 feet deep (being one of the deepest borings ever made), and more than 1,700 feet of it is lined with copper tubing, which was placed there instead of some wrought-iron tubing, with which it was originally lined. The copper tubing begins at 12 inches in diameter and goes down to 6½. The temperature of the water in this well at about 1,800 feet is as much as 82 F., and you may put it down that as a rule, the temperature of the water increases 1° F. for every 50 feet below the surface. Of course there

are certain places where it increases very much more (about Bath for instance), but these are exceptional cases. The boring in the well at Trafalgar-square is sunk 384 feet from the surface into the chalk, and it yields 65 cubic feet in a minute, or more than 580,000 gallons in the 24 hours. There is a well in Woolwich in the chalk 580 feet deep, which yields 1,400,000 gallons in 24 hours, and the last I am going to mention in the chalk is a well near London—the Amwell hill well—close by the source of the New River. That is only 171 feet deep, and it is said to yield very nearly 2½ million gallons in the 24 hours. (Hughes on "Waterworks.") As all this water underneath the London basin comes originally from districts at some distance from London, it is not to be wondered at that the pumping at London lowers the level of the water in the wells in those districts. These are examples of successful borings. Now, a word with regard to the new red sandstone wells of Liverpool. These wells you will find described in the twelfth volume of the proceedings of the Institution of Civil Engineers. One of them called the "Bootle Well" has many points of interest about it. Its maximum yield was, in 1853, about 1,100,000 gallons in the 24 hours. A curious point about it is that at the bottom of the well instead of there being one boring there are 16 or 17. These 16 or 17 borings are of very different depths, and it became very interesting to know whether the whole of them were of any use, and Mr. Stephenson thought of blocking them up, all but one. He did so, and found that one yielded very nearly as much water as the 16, so that a very considerable amount of capital had been wasted in the boring of these holes. That is worth knowing. There are six other public wells at Liverpool in this new red sandstone, and the ordinary yield was about 4½ million gallons daily from them all. This was in 1850. Eighteen years afterwards, evidence was given before the Commissioners on the Water Supply for the Metropolis of a falling off in the water supply of these wells. In fact, the continual pumping had diminished the supply. In 1854, these wells in the new red sandstone at Liverpool were pronounced failures by Mr. Rawlinson, as also were others in England and America, and Mr. Piggott Smith, in a report on the water supply of Birmingham, confirmed this, and it is a fact that they have had to be supplemented by a supply of much superior water from a distance. Mr. Stevenson estimated the cost of a pumping station for one of those Liverpool wells, including shafts and steam engines, at £20,000, and the annual cost per million gallons a day at £1,324, this being without interest or compensation, but including depreciation. Generally, well waters are liable to vary in amount from month to month, and from year to year, as witnessed by the amounts pumped from these Liverpool wells, and by the amounts pumped year after year from the Cornish mines.

After wells, the next thing we have to consider is the way in which water can be collected from springs and streams over a large area, called a drainage area. That is one method of supply, and the other method, of course, is pumping from rivers. We tell the amount of water that can be got from a large surface of land, in the first place, by a way I spoke to you about before, viz:—by estimating the amount of available rainfall on it. Then we can tell it in another way, by correctly measuring the amount of water that is brought down by streams and springs; so that we have to consider the methods used for gauging springs, streams, &c. The gauge most commonly in use is the one known as the Weir gauge. Weir gauges are made by damming up the stream, and making it all pass over a sharp ledge or through an orifice or notch, or row of notches, on a vertical board. Then from formula you can, by means of tables, calculate the amount of water that passes through the notch, or over the orifice of the weir in a given time. You determine the height of the still water by means of a scale, the zero of which is level with the base of the notch, and you do it in this way. A stick is planted in the bed of the stream, its top at some little distance from the weir, and so that its top is level with the base of the notch, or row of notches, in the weir, and then you measure by the scale from the top of this stick to the level of the water from the orifice. That is one way. The next plan is by calculating from the declivity.

This is only applicable to regular channels, like the New River for instance, and if the stream is small you can make the whole of it pass through a trough, and then calculate the velocity from the declivity. Another way is by measuring the maximum surface velocity, which is done by means of floats of any sort, or by means of fan wheels, and various little instruments for measuring the surface velocity of streams. You take the maximum surface velocity, and about three-fourths of this will represent the mean velocity of the section. The discharge of springs is estimated by the time taken to fill a vessel of known capacity. A word about the permanence of springs and streams, which is an extremely important point. In the first place you must try and get evidence from maps and trustworthy sources generally. At the bases of hills springs are usually permanent. In flat countries you may put it down that the reverse is generally the case. Springs in limestone countries are very permanent. Springs in very permeable strata are very generally variable, unless they are tapped at a considerable distance from the surface, and then they often give an enormous yield.

Springs in primary strata, and in granite countries are very often very permanent indeed, and it is in these countries you have some of the large lakes which are used for supplies of water. In clay basins the water supply is variable as a rule, being very great in the winter, when there are often floods, and very small in summer. In chalk countries the springs are more permanent, for the reason that they draw from considerably beyond the actual basin. Intermittent springs sometimes occur, especially in the chalk; they are due to the gradual collection of water in subterranean hollows, which when filled above a certain level empty themselves by means of a syphon shaped outlet; it is obvious that they must not be relied on as sources of a supply of water. This will end our consideration of the merits of different localities from the water supply point of view.

THE IRON ORES OF SWEDEN.

By Mr. CHARLES SMITH, Barrow-in-Furness.

Journal of the Iron and Steel Institute.

Although the iron trade of Sweden is on a very small scale compared with that of England, the quality of much of the metal manufactured is of so high a character, that the subject has an importance far beyond the mere question of the quantity produced. In round numbers, England makes twenty times as much iron as Sweden; the Furness district alone producing more iron and iron ore than the whole of the latter kingdom. Notwithstanding this comparative insignificance in quantity, the Swedes, with their wonderfully pure ores, have succeeded in manufacturing iron which, in many branches of trade, appears for the present to be a necessity, and which is perhaps the finest in Europe. On these considerations, I hope that a brief account of the Swedish iron ores may prove not uninteresting to many members of the Institute.

The iron ores of Sweden are, with an insignificant exception, of one class; and though they vary considerably in their iron percentage, and to some extent in other constituents, they have a very great external similarity. The ore is either Magnetite or Red Hematite, containing every percentage of metallic iron, from 30 per cent. to almost chemical purity, which, for the former would be 72, and for the latter 70, per cent. The hematite, called "bloodstone," gives the same streak as the English red hematites, but is externally scarcely distinguishable from the magnetite; both kinds are named in Swedish "Mountain ores;" they have a slightly different aspect from the Spanish and Algerian magnetites, but possess nearly the same blue-black color.

A small varying quantity of Brown Hematite is procured in the south of

Sweden, from the large bogs of Smaland; and in winter a similar ore is dredged from the bottom of certain lakes in the same province. The average of this ore would probably not exceed 25 per cent. metallic iron, though it occasionly contains 50 per cent.; frequently it is so intermixed with sand as to be of little value; phosphoric acid is generally present, sometimes up to 4 per cent.; manganese is often a constituent, and in a few places has a strength of 20 per cent. The yearly quantity raised of this ore is as varied as its composition; in 1855, it was 12,000 tons; in 1860, 20,000 tons; in 1866, 8,000 tons; in 1867, 17,000 tons; in 1869, 6,000 tons; in 1871, 15,500 tons; in 1872, 12,000 tons.

The other ores of iron, with trifling exceptions, do not occur in Sweden. The red and brown hematites and the oolitic ores, such as those we have in England, are absent altogether; chalybite, the white carbonate, is found in hand specimens in a few of the metalliferous mines; and a thin insignificant bed of argillaceous iron ore has been met with in the Skane coalfield.

Judging from official returns, the average yield of the "Mountain" ores, throughout the kingdom is under 50 per cent. metallic iron. In 1872, from 671 mines, 718,000 tons of ore were raised, and 333,000 tons of iron manufactured; but of the former, 12,000 tons were bog and lake ores, with very low percentages, and about an equal quantity of the "Mountain" ores was exported to Finland. Besides the iron oxide, the main constituent of the ores is almost invariably silica. Lime, magnesia, and alumina are generally present; the last usually in the smallest quantity. Phosphorus has rarely a greater strength than 0.05; though in some ores, not worked, upwards of 1 per cent. is found; and it sinks to 0.004 at Persberg, and to 0.003 at Dannemora. Sulphur, with a few marked exceptions, is not generally present to a much greater extent than phosphorus.

The surface of Sweden is mainly covered by plutonic rocks, of which granite is the most abundant, although large areas are occupied by gneiss, mica slate, and every variety of porphyry; there is also a felspathic rock peculiar to Sweden, termed "Helleflinta," or Leelite, which, though small in quantity, is of great importance in reference to iron, as this metal is nearly always present where Helleflinta occurs. Over a vast area, in these granitiferous rocks, iron ore is found in greater or less abundance; though, doubtless, the iron districts are still most imperfectly known, as so much of the country, especially in the north, is for iron-making purposes inaccessible. Far in the north, beyond the head of the Gulf of Bothnia, the iron deposits of Gellivara are probably the richest in the world; but the rigor of the long winter has, hitherto, prevented any commercial success in the working of the mines; and, according to the Government returns, the annual production does not reach 50 tons of ore. More to the south, a few small mines are worked, but only on the most limited scale, until the parallel of Gefle is reached. We may, perhaps, assume that future research will prove that Sweden possesses the greatest stores of her purest ore in her most northern provinces; but we can scarcely hope that these can be made available, without changes in value taking place that, at present, cannot be anticipated. In the southern portion of the kingdom very little ore is raised. The main bulk is obtained from the central provinces. The counties of Kopparberg and Orebro alone produce 50 per cent., and Westmanland and Wermland 30 per cent. of the whole yield.

Iron ore is by far the most important Swedish mineral. The "Mountain" ores occur in veins, which are sometimes regular, but more generally are deflected from a straight line, and occasionally even form a semicircle. Usually they have a north-east to a south-west direction, though north to south and east to west veins occur. Their width varies from mere strings up to, as at Schysshyttan, 200 feet. Probably 30 to 50 feet would be the general strength of the veins now worked. In some instances, these can be traced for some distance along the surface; but, commonly, they dip down at a steep angle. As so many are known, few have been thoroughly explored as to their depth; when worked to 200 or 300 feet deep, other shallower veins have been started, except in the more important deposits.

The mode of formation is, as yet, an unsolved problem. Many difficulties present themselves in opposition to each of the more popular solutions. The veins are occasionally found in gneiss ; at other times in granite; but, generally, they are separated from their granitic surroundings by a band of Helleflinta, which is usually only present in small quantities; but at Persberg, the largest mine in Sweden, the surface for two miles in one direction is composed of it. In some cases, the veins descend perpendicularly; and in at least one instance (at Persberg), the vein, after so doing, makes an elbow at right angles and lies horizontally.

It is commonly believed that the ore is an aqueous deposit, probably from hot water. Though numerous facts support this theory, many will not coincide with it ; perhaps the chief being that there is not the slightest external appearance of the ore being a water deposit, as it is in solid irregular masses, lying in equally solid rock, which in those cases where granite overlies is unquestionably plutonic. Assuming that Helleflinta is an altered clay, which has by no means been proved absolutely, and that both it and the ore were deposited simultaneously, there would be some mechanical mixture of the two, and not the perfect demarcation that exists. If the ore were an aqueous deposition, it must necessarily have been, at some time, horizontal; and whatever the convulsions were, which could, as in the Persberg instance, tilt up one end of the vein to the extent of 90°, they could not do this without a great dislocation of both the vein and the surrounding rocks, whether it happened before or after the solidifying of the ore and the Helleflinta, and this is not the case.

In certain instances the iron oxide is found interspersed in grains for some distance on either side of a vein, which becomes more and more rich as it approaches the centre, where is the purest part. It is difficult to account for this on any ordinary aqueous or ingenious theory.

The peculiar magnetic properties of much of the "Mountain" ore offer little assistance to the solution of the problem of its formation. The magnetite and hematite are found closely intermixed, the one highly magnetic, the other not affecting the needle; the ores being similar in appearance and constituents. Some masses of magnetite are much more magnetic than others, affecting the compass through 20, or even 50, fathoms of intervening rock ; whilst to some bodies of equally true magnetite, the needle will not dip, though not more than 10 fathoms of rock intervene.

In several districts, especially in the Norberg mines and, to a less extent, in those near Nora, the ore has a very singular striped appearance, caused by numerous veins, or nearly parallel layers, of crystallized quartz lying amongst the ore.

May I be allowed to suggest that, perhaps electricity may have been the chief agent in the formation of these mineral deposits. It is difficult to understand in what possible way they could be formed by volcanic action ; and it appeared to me to be equally impossible to understand how these veins of iron ore, which dip steeply over immense areas of country, could owe their origin to water, without exhibiting some trace of aqueous deposition; especially when their centres are the purest part, whilst they gradually on either side pass imperceptibly into the surrounding rocks. It seems still more difficult to account, either by the aqueous or igneous theory, for the finely veined ores of Norberg, which consist of thin parallel layers of magnetite and crystallized quartz. But what might be difficult or impossible for fire or water to accomplish, might perhaps be effected by electricity, if we assume that currents may have acted, in definite directions, for long periods of time, segregating the particles of iron oxide, which exist in a slight percentage throughout vast masses of many Swedish rocks.

Although there is so strong a similarity amongst all the Swedish "Mountain" ores, there is generally a sufficient divergence, in chemical composition, to give a separate character to most of the districts, and to some of the individual mines.

Pre-eminent for its purity is the best Bispberg ore, which contains up to 70 per cent. metallic iron, or almost a chemically pure oxide ; only a small proportion reaches this high standard, the bulk

of the output varying from 50 to 60 per cent. The mines, which are thirty miles south-east of Fahlun, claim an antiquity of 600 years; they are very small, producing under 15,000 tons per annum. On account of the purity of the ore it is much esteemed as a mixture, but from the isolation of the mines it becomes very expensive to most of the works which use it. From the working drawings, it does not appear as if the production could be much increased. The greatest depth is about 700 feet, with the vein, which lies in quartz and talc-schist, dipping steeply.

Much the largest iron mines in Sweden are those at Persberg, near Filipstad, in Wermland. The veins, of which the largest is 66 feet at its greatest width, lie altogether in Helleflinta. The deepest workings are over 600 feet below the surface, the largest 400 to 500 feet. The annual production has lately been between 50,000 and 60,000 tons. The ore rarely contains less than 50, and rises to 60 per cent. metallic iron; it is much valued for furnace purposes, for its purity and freedom from deleterious ingredients; it commands a higher price than that from any other large mines, and, to a great extent, the iron ore market of that part of Sweden is regulated by its selling price. Persberg is said to have been worked for 800 years.

The most famous of the Swedish iron mines are those at Dannemora, in Upsala County, away from the main iron districts. The annual production is under 25,000 tons, and has varied but little for over 20 years. The ore contains from 25 to 60 per cent. metallic iron; very little has over 50 per cent., and the average is much below; most contains sufficient lime and silica to be smelted without a flux; it has also about 2 per cent. manganese. The highest percentaged ore does not make the best pig iron. The mines have been worked steadily for four centuries; the largest is in three sections, the centre, an open-work, being the chief. The main vein is somewhat irregular; it has an average width of 100 feet, being 150 at the widest, and has been explored 900 feet in length in the open-work, which is 200 feet wide, with walls, either perpendicular or slightly overhanging, of over 500 feet in vertical depth. The bottom of this extraordinary mine was covered, during my visit in the month of August, with large blocks of ice. The veins lie in Helleflinta, of which there are several varieties; different trap rocks are present, with granite and gneiss. The production of the mines might be greatly increased, but they are held under a tenure that prevents more than a certain quantity being raised. The ore is never sold, but goes solely to the furnaces of the different joint proprietors. The largest owner is Baron De Geer, the representative of a Dutch family, who, in the 17th century, acquired a practical monopoly over the iron trade of Sweden; most of their works and mines have passed into other hands, but they still retain Lofsta, where is manufactured, from Dannemora ore, the L iron, the dearest in Europe of its class.

A new railway will shortly open up the Grangesberg district, in Dalecarlia, which, it is considered, may prove the most productive in Sweden. At present the mines are cramped by expensive transit. The ore in the most southern part of the district is of very high quality, and free from phosphorus; but this ingredient increases regularly in a northerly direction, until in the extreme north the ore is of little value.

The mines round Norberg, in Westmanland, produce about 70,000 tons per annum of ore, which contains from 45 to 50 per cent. metallic iron. The striped appearance of this ore, caused by fine layers of quartz amongst the iron oxide, is peculiar. Notwithstanding its large percentage of silica, it makes good iron. The veins are from 20 to 50 feet wide, and lie in gneiss, but are separated from it by bands, on either side, of Helleflinta. About three years ago, a new ore was discovered here, containing 35 per cent. iron and 20 per cent. manganese, which it was hoped might produce spiegeleisen; but it is understood that the experiments have not been successful.

In the neighborhood of Nora, in Orebro County, there are many mines; those at Striberg are second only to Persberg in production; but the ore is the poorest in the district, with only 48 to 50 per cent.; whilst at Dalkarlsberg, which is the deepest iron-mine in Sweden—about 800 feet—the best ore has 68 per cent.

metallic iron, and very much rises to 60 per cent. Much of the Nora ore contains manganese; at the Wickers mines up to 9 per cent. The manganiferous ores almost always contain mundic (sulphuret of iron); in some cases they have to be calcined twice to drive off the sulphur; they are also much more close-grained in appearance than ordinary magnetite, and some becomes brown with two or three days' weathering. Many of the Nora veins are red hematite, which rarely contains over 55 per cent. metallic iron. Some of the magnetic veins have been proved over a thousand yards in length.

For the Bessemer steel trade, by far the most important mines in Sweden are those at Schysshyttan, 10 miles from Smedjebacken, in Delecarlia. The ore is a mixture of magnetite and knebelite; the latter, a very rare silicate of manganese and iron, met with at Dannemora and a few other localities, but nowhere, except at Schysshyttan, in any quantity. The combined minerals contain 50 per cent. iron and manganese; they produce, without the addition of any other ore, the highest class of spiegeleisen. The vein, which has more the appearance of a lode, can be traced along the surface for a considerable distance; it is 200 feet in breadth, and has been proved to 300 feet in depth, without any appearance of the bottom; the centre of the lode is the best; at the edges the ore is not good.

Far to the south of the general iron district, near Jönköping, in Smaland, is the remarkable hill of Taberg. As far as has been ascertained, this hill, which rises 380 feet above the level of the surrounding country, is a solid mass of close-grained serpentine, containing on the average about 30 per cent. metallic iron, and which is in appearance very like some of the hematite ores of the north. Two sides of the hill are perpendicular, and form quarries, whence has been taken for years the supply of ore for a dozen furnaces, which altogether have only an annual production of 3,000 tons pig iron. This iron has been found well suited for a few purposes, and is very tough; but the demand is limited. The heavy percentage of magnesia in the ore has hitherto been an insuperable obstacle to any large manufacture. Were this difficulty overcome, this hill would be one of the most valuable iron mines in the kingdom.

The foregoing are the chief representative iron mines in Sweden, either for quantity of production, or quality of ore. All the mines are much alike in character, with the exception of Dannemora partly and Taberg wholly, as the mode of working is almost identical. In some cases the veins of ore come to the surface; but generally they are discovered by a magnet of peculiar construction, so made that the needle can dip as freely as turn horizontally; as soon as these magnets come over a body of magnetite, the needle swings round and points downwards to the mineral. When the presence of the ore is ascertained, a large hole is usually made down to the vein, which may be worked open for a short time, but as most dip at a steep angle, the ore is mainly obtained by mining. As the walls are solid, only a trifling amount of timber is used, often none at all. The surrounding rocks are so firm, that it rarely happens any are brought down by the constant blasting; the only one that I saw, during a lengthened tour through the Swedish Iron districts, which had given away, or become unsafe, by the rock crushing, was at Guldsmedshyttan, in Orebro County. The whole of the "Mountain" ores, without any exception, have to be blasted. The small shafts, that may have to be sunk through overlying granite drift, are frequently of very rude construction, bound round with withes and, if not round, of no regular shape. The drainage of the mines gives much trouble; except where steam is unavoidable, hydraulic power is always used, and often the pumps are worked by bobs of immense lengths.

Royalties in Sweden belong half to the landlord and half to the discoverer of the mineral; but the former may take half the mine, if he elect to do so. On finding any deposit, in the case of iron by magnet or otherwise, an application is made to a government official, termed bergmaster, who grants a certificate of ownership, should no adverse claim be presented and proved within a given time. These bergmasters, of whom there are ten, have each a separate district, the whole kingdom being divided amongst them. They have very consid-

erable power, and appear to settle almost all mining disputes.

The value of the iron ores varies to a great extent, depending not only on chemical composition, but also to a very great degree on local position. It must be remembered that the key to the Swedish iron trade is not the mineral, but the fuel, supply. This latter has been annually growing in relative importance, until lately it has become the chief particular. Charcoal still remains, notwithstanding the importation of foreign coal and coke, the main fuel of the country; and as it deteriorates most materially in transit, the fuel supply determines the locality of most of the Swedish works. Often ore is carted 20 or 30 miles, or transported over 100 miles by road, canal, and railway; whilst furnaces have been built in Finland, where there is but little native ore; or in the Hernosand district, up the Gulf of Bothnia, where there is scarcely any, to save carriage on the charcoal. The ore in this way has, often to bear a most burdensome carriage, and its cost varies for every works. As far as possible, the annual supply is laid in during the winter, as it is more cheaply transported over the snow and ice, than by road in summer. Many furnaces are dependent on a hard winter for obtaining any supply at all; and such during a winter like the past mild one, when there was scarcely any snow, are obliged to be blown out. When the furnace proprietor raises his own ore, the cost varies probably from 3s. to 16s. per ton, delivered at the works; and some of the best ores are worked the cheapest. Norberg ore, with 50 per cent. iron and much silica, is quoted about 16s. per ton, delivered at Stromsholm, on the Malar Lake, where sea-going vessels can load. Ordinary ores, with a little over 50 per cent. iron, are sold in Wermland and in the Nora district, at about 27s. per ton, delivered on the railway or at some mining centre. Persberg ore would be more expensive, and is quoted on a sliding scale according to percentage. Dalkarlsberg ore, when containing 68 per cent., is quoted over 30s. per ton, delivered on the railway. The majority of these ores would have to bear heavy carriage in addition to these prices, which are from 50 to 100 per cent. higher than in 1871.

In conclusion, I have only to regret that this sketch does so little justice to the subject undertaken, but I shall be satisfied if it has enabled the members of the Institute to obtain a clearer perception of the marvelous resources in iron ores possessed by Sweden. At present the iron trade in that country is cramped by want of fuel, labor, capital, and means of transit. But every year now should lessen these deficiencies, and we may, perhaps not without reason, look forward to a not distant future, when the iron trade of Sweden will be of European importance, not alone from the quality, but also from the quantity, of the metal produced.

ELEMENTARY DISCUSSION OF STRENGTH OF BEAMS UNDER TRANSVERSE LOADS.

By Prof. W. ALLAN.

Written for Van Nostrand's Engineering Magazine.

I.

In the following discussion the ordinary cases of loaded beams are treated without resorting to the higher mathematics. It is an attempt to compile from various sources the simplest methods of treating such cases as arise most frequently in practice.

Transverse stress is produced by a load applied to a beam in a direction perpendicular, or inclined, to its length. AD

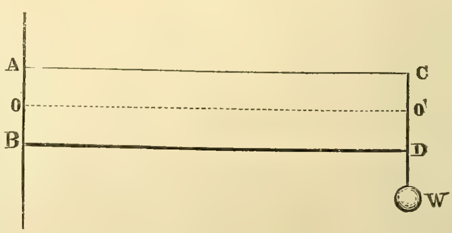

Fig. 1.

(Fig. 1) is a beam subjected to such a stress.

In this kind of stress a compression of the particles or fibres on one side of the beam, and an extension of those on the other, are produced. In consequence of this the beam *bends*. Experiment shows that the amount of compression on the one side, and of extension on the other, diminishes as we go inwards from the top or bottom towards the centre, and at some intermediate plane, O O′, becomes zero. The fibres at this plane being neither lengthened nor shortened, it is called the *neutral* plane, and its intersection by the plane of vertical section is called the *neutral line or axis*. Experiment also shows that, from this plane towards the top and bottom, the amount of extension and compression may, for the stresses that occur in ordinary practice, be considered as varying directly with the distance from the neutral plane.

The extreme top and bottom fibres suffer the greatest compression and extension, and in case of rupture, the rupture begins with them. Some question exists as to the exact location of the neutral line or plane, but for slight deflections it passes through the centre of gravity of the cross section of the beam, and it is very probable that it never deviates from this position.

In discussing transverse stress, the assumptions based upon experiment may be stated as follows :

1. The forces on the fibres are directly as the amount of extension or compression they produce ; (*Ut tensio sic vis,*) and since the extension and compression increase as the distance from the neutral axis, the forces vary in the same proportion.

2. Within *elastic limits* the extension and compression at equal distances from the neutral axis are equal, and the forces producing them are equal.

3. The *neutral axis* passes through the centre of gravity of the cross section.

RECTANGULAR BEAMS.

Let us now discuss the relations existing between the forces in, and on, transversely loaded rectangular beams, the load being supposed to be vertical in direction and the beam horizontal.

Case I.

Let AD (Fig. 2) be a beam so thin that it may be considered as composed

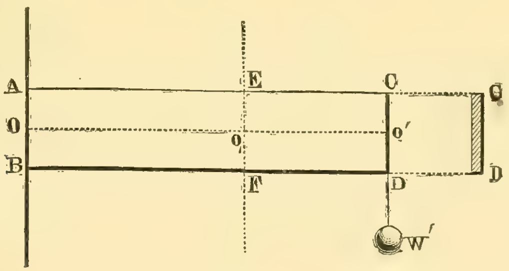

FIG. 2.

of but one layer of fibres or particles. Let it be fastened in a wall at A B, and be loaded with W′ at the other end. Neglect for the time the weight of the thin beam itself, which is small. Imagine it to be cut by a vertical plane E F at any point, and let us see under what forces the part E D is held in equilibrium.

The only external force on E D is W′ acting at D downwards, and E D is prevented from falling under this weight by the *resistance of the fibres* at E F. To analyze these forces, let us take O_1 as an origin of coordinates, and $O_1 O'$ as the axis of x, and O_1 E as the axis of y, and as the forces are all in one plane, find their components along these axes. The *internal* forces, or resistance of the fibres at E F, are :

1. The *horizontal forces* which are tensile above and compressive below, and which increase from zero at O_1 just in proportion as we go from that point

towards the upper or lower edge of the beam. (Fig. 3.)

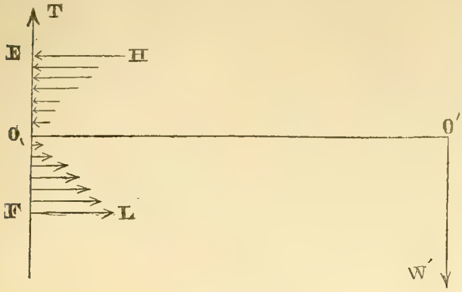

FIG. 3.

2. The *vertical force*. This is called the *shearing force*, or *transverse* shearing force. It resists the tendency of the part of the beam E D to slide down on the surface E F. The existence of this force may be realized if we conceive the beam to be divided into two parts by the vertical plane E F, and those parts to be united by some very elastic substance, as india-rubber. Then the beam would take the form shown in Fig. 4, the part F C sliding down on the other. The force in the beam that resists this sliding is represented in Fig. 3, by the vertical

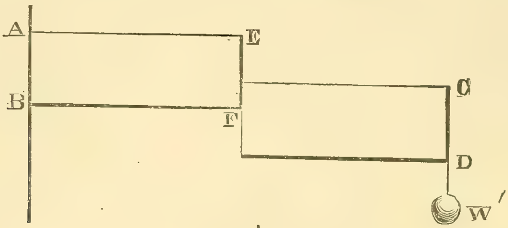

FIG. 4.

arrow at E. Let it be called T. In Fig. 3 are represented all the forces we have to deal with. Since this system of forces is balanced, the following equations must be fulfilled :

$$\Sigma X=0 \quad \Sigma Y=0 \quad \Sigma M=0 \qquad (1)$$

That is : the sum of all the horizontal forces (ΣX), and the sum of all the vertical forces (ΣY) must each be equal to zero, and the sum of the moments about any point as O_1 must also equal zero.

The only horizontal forces in the system are the two triangular groups of forces $E\,O_1\,H$ and $F\,O_1\,L$, representing the sum of the tensile and compressive stresses on the fibres. As the group $E\,O_1\,H$ acts in a direction opposite to that of the group $F\,O_1\,L$, and as the algebraic sum of the two groups is zero ($\Sigma X=0$), the groups must be equal to each other. This is indicated in the figure by the equality of the triangles $E\,O_1\,H$ and $F\,O_1\,L$.

The vertical forces are W' and the shearing force T at E F, and since

$$\Sigma Y=T-W'=0. \quad \text{We have}$$

$$T=W' \qquad (2)$$

Next obtain the moments of all the forces about O_1 and place the sum of these moments = zero. Replace the

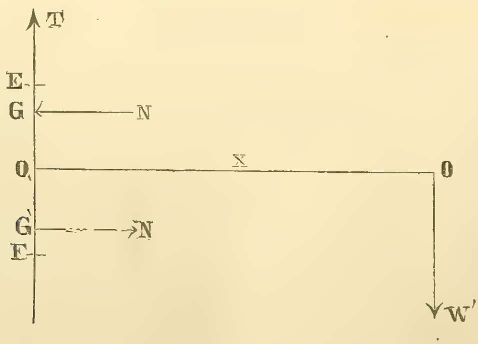

FIG. 5.

tensile and compressive forces by their resultants. The resultant or sum of all the tensile forces represented by the triangle $E O_1 H$ (Fig. 3) may evidently be represented by the area of the triangle of which the base $E O_1$ is the distance over which the forces are distributed, and the altitude $E H$ is the stress in the outside fibre. Let

$$S = \text{this stress} = E H$$

and $\quad d = E F = \text{depth of beam}$

Then area $E O_1 H = \frac{1}{4} S d = N =$ resultant of tensile forces. Similarly

Area $F O_1 L = \frac{1}{4} S d = N' =$ resultant of compressive forces.

These resultants will pass through the centres of gravity of the triangles $E O_1 H$ and $O_1 F L$, since the little forces of which they are composed are represented by these triangles. Hence the direction of N will intersect $O_1 E$ at a point G (Fig. 5), whose distance from O_1 is $= \frac{2}{3} E O_1 = \frac{2}{3} \cdot \frac{d}{2} = \frac{d}{3}$. This is the lever arm of N about O_1. That of N' is $G' O_1$ also $= \frac{d}{3}$. Hence the sum of the moments of these two forces about O_1 (since they both tend to produce left-handed rotation) is

$$-N \frac{d}{3} - N' \frac{d}{3} = -\frac{1}{6} S d^2$$

The force T since its direction passes through O_1 has no lever-arm, and hence its moment is zero.

If the distance from O' to O_1 be called x, the moment of the weight W' is $= + W' x$ (since it tends to produce right-handed rotation)

$$\therefore W' x - \frac{1}{6} S d^2 = \Sigma M = 0$$

$$\therefore W' x = \frac{1}{6} S d^2 \qquad (3)$$

So far we have considered a beam whose breadth is that of only one row of fibres, but a beam of any breadth may be made up of a number of such slices placed side by side, and if $b =$ the number of slices, or breadth of the beam, and $W =$ the weight hung at the end of it, then eq. (3) becomes

$$W x = \frac{1}{6} S b d^2 \qquad (4)$$

This discussion is general and will apply to any section as well as to $E F$. S and x are the variables in eq. (4), and these quantities will have different values at the different sections, which values increase as we go towards $A B$ (Fig. 2), but the form of the equation will evidently be unchanged. If $A C$ (Fig. 2) be $= l$, we have for the section at $A B$ (Fig. 2)

$$W l = \frac{1}{6} S b d^2 \qquad (5)$$

$A B$ is the section of greatest stress, and the beam if overloaded will break there.

The quantity $\frac{1}{6} S b d^2$ is called the *moment of resistance* of the fibres, or moment of the internal forces, and is often written M for brevity. Wx is called the moment of the weight, or moment of the external forces. Let the maximum value of $\frac{1}{6} S b d^2$ (eq. 5) be called M_0.

We may illustrate geometrically the variation of the moments $M = W x$, and consequently of the stresses produced on the outside fibres from A_1 to C.

In Fig. 6 let $A C$ be the beam. Take

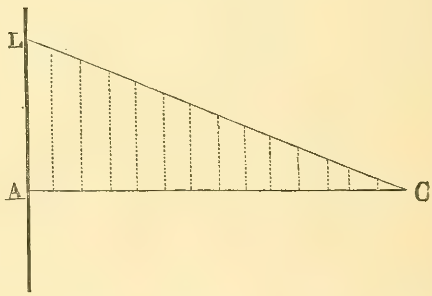

FIG. 6.

a line on some scale to represent the value of $M_0 = W l$, and lay it off from A perpendicular to $A C$. Let $A L$ be this line. Draw $L C$. Then the dotted perpendiculars in the triangle $L A C$ will represent the moments of resistance in the beam at the several points at which they are drawn.

From eq. (2) it is seen that the shearing force is constant at every section of the beam. This force we may assume with sufficient accuracy, for our present purpose, to be uniformly distributed over

the cross section of the beam on which it acts. Hence if A = area of cross section, and t = shearing force on a unit of the surface,

$$T=W=At \qquad (6)$$

Lay off A C (Fig. 7) $=l$ and C P=W. Then the rectangle A P represents geometrically the shearing stress at every point of the beam.

Corollary. When several weights as W W_1 W_2 (Fig. 8) are suspended from

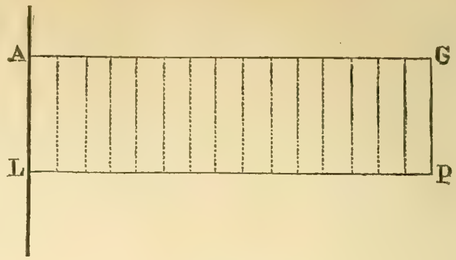

Fig. 7.

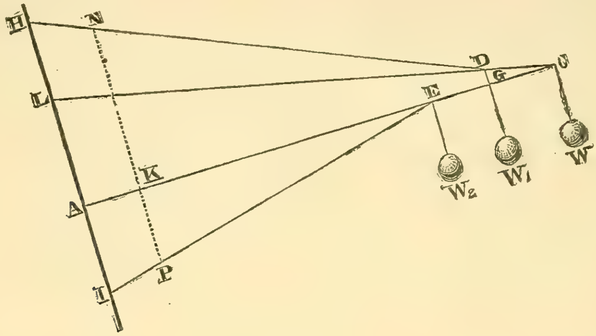

Fig. 8.

the beam at different points, the moment of resistance at any point is equal to the joint moments of the weights at that point. Thus, calling distances measured from C, G, and E towards A, x, x_1 and x_2 respectively, we have for the equation of moments for points between C and G

$$W x=\frac{1}{6} S bd^2$$

Between G and E

$$W x+W_1 x_1=\frac{1}{6} S b d^2$$

While at K, for instance, it is

$$W x+W_1 x_1+W_2 x_2=\frac{1}{6} S b d^2 \qquad (7)$$

The shearing force at K is

$$T=W+W_1+W_2 \qquad (8)$$

Geometrically. Let A C (Fig. 8) $=l$ A G$=l_1$ and A E$=l_2$. Lay off A L$=W l$, L H$=W_1 l_1$ and A I$=W_2 l_2$. Draw the triangles as in Fig. 8. Then N P=total moment at K, for instance.

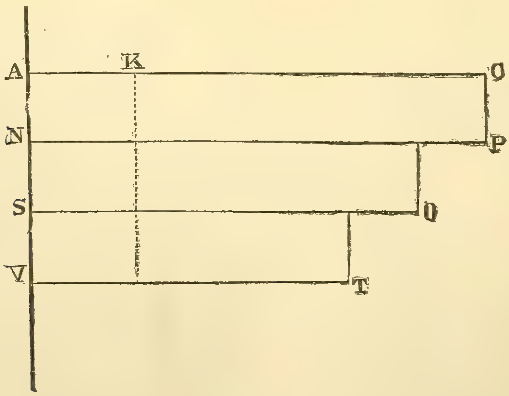

Fig. 9.

The shearing force is represented by the rectangles A P, N O, and S T (Fig. 9), and at any point in the beam is equal to the sum of the weights between that point and C.

EXAMPLES.

(1.) Suppose the safe stress per square inch to be 1,000 lbs. (= S), and $l = 10$ ft., $b=3$ inches, and $d=12$ inches, what weight will the beam support ?

(2.) Suppose $W=\frac{3}{4}$ ton, $l=12$ ft., $b=2$ inches, what must be the depth (d) of a rectangular cast iron beam, so that S shall not exceed 4 tons?

Case II.

Let the beam be as in the last case, but with the load distributed uniformly over it (Fig 10). Let w=weight on a

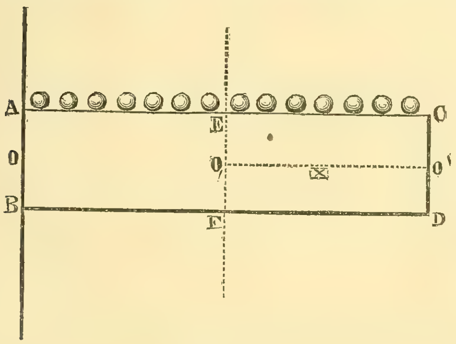

FIG. 10.

unit of length, W=total weight on A C, l=A C=length, d=A B=depth, x=E C as before. Then the forces to be considered are represented in Fig 11, the little arrows along E C representing the weight distributed along the beam.

Replace the weights along E C by their resultant, which is $= wx$, and which should be applied at the middle point of E C, since the little weights on the beam are uniformly distributed. Then putting the resultants N and N′ in place of the tensile and compressive force, and proceeding as before, we have

$$T - w\,x = 0$$

$$T = w\,x \qquad (9)$$

Also $$w\,x.\frac{x}{2} - \frac{1}{6}\,S\,b\,d^2 \quad = 0$$

$$\frac{w\,x^2}{2} = \frac{1}{6}\,S\,b\,d^2 = M \quad (10)$$

At A B (Fig. 10) these equations become

$$\left.\begin{aligned} T_0 &= w\,l = W \\ \frac{w\,l^2}{2} &= \frac{W\,l}{2} = \frac{1}{6}\,S\,b\,d^2 = M_0 \end{aligned}\right\} \qquad (11)$$

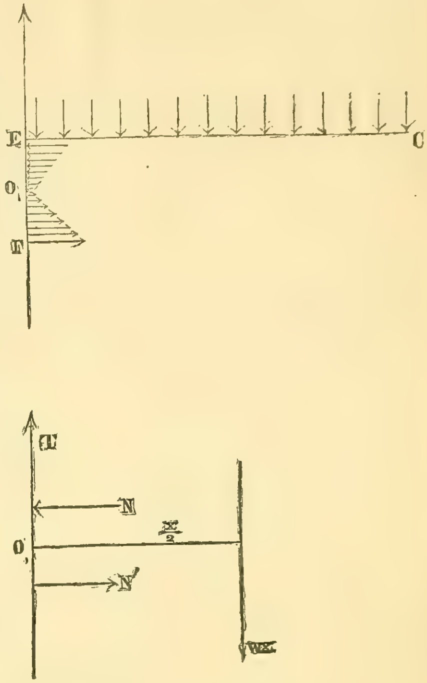

FIG. 11.

By comparing the last equation with eq. (5), we see that if the weight and beam be the same the stress on the fibres in this last case is only *one-half* what it was in the former, or, what amounts to the same, the beam will bear twice as much distributed over it, as it will when the weight is concentrated at the extremity.

From eq. (9) we see that the shearing force is not constant as in the last case, but varies as x. It is greatest at A.

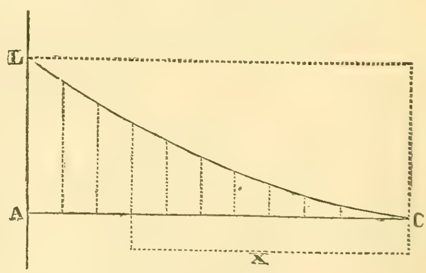

FIG. 12.

Geometrically. The equation $M=\frac{1}{2}wx^2$ corresponds with that of a parabola with vertex at C and axis vertical. Lay off AL (Fig. 12) $=\frac{1}{2}wl^2$, and through L and C draw a parabola. The ordinates of this parabola (dotted in the figure) will represent the moments at the several points.

The equation $T=wx$ is represented by the triangle APC (Fig. 13), which

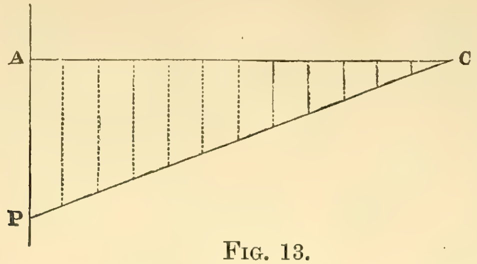

FIG. 13.

therefore gives the shearing stress at every point of the beam when AP is taken $=wl$.

Corollary 1. When the load is distributed over only a part of the beam as in Fig. (14), let $RC=m=$the loaded

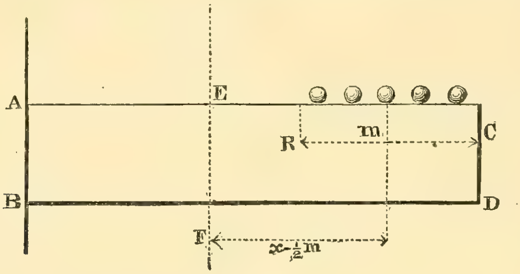

FIG. 14.

part, and take the other letters as before. Then the equations for any section in the loaded part are evidently the same as those just obtained, viz.:

$$\left.\begin{array}{ll} & \frac{1}{2}wx^2=\frac{1}{6}Sbd^2=M \\ \text{At R} & \frac{1}{2}wm^2=M \\ \text{And} & T=wx \end{array}\right\} \quad (12)$$

But at any section EF between A and R the moment of the load is $=wm(x-\frac{1}{2}m)$, the latter factor being the distance from the centre of gravity of the load to the section EF. The moment of resistance having the same form as before, we have for the equation of moments for any section in RA

$$wm(x-\tfrac{1}{2}m)=\frac{1}{6}Sbd^2=M \quad (13)$$

At A this becomes

$wm(l-\frac{1}{2}m)=M_0$ the greatest moment.

The shearing force at EF being equal in amount and opposite in direction to the whole load between EF and C will be

$$T=wm \quad (14)$$

Geometrically. For the moment S: lay off $AC=l$ and $CR=m$ (Fig. 15). At

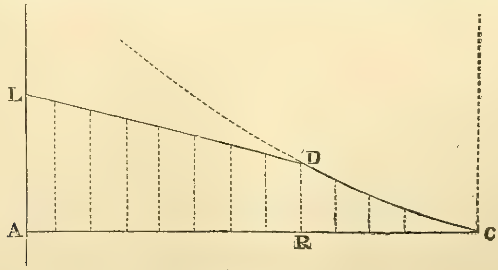

FIG. 15.

R erect $DR = \frac{wm^2}{2}$, and at A make $AL = M_0$. Through C and D draw a parabola as in the last case, and (since eq. [13] is of the first degree) through D and L draw a straight line. Then from C to R the ordinates of the parabola represent the moments, and from R to A they are represented by the ordinates of the trapezoid R L. For the shearing stress (Fig. 16), lay off from R, $RN = wm$.

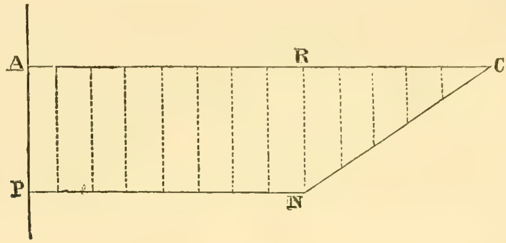

Fig. 16.

Draw C N and N P. Then the triangle C R N (corresponding to the equation $T = wx$) gives the shearing force at each point in C R while the rectangle R P (corresponding to the equation $T = wm$) gives the force in the remaining segment of the beam.

Corollary 2. When there is a load W at the extremity C, in addition to the load uniformly distributed over the beam (Fig. 17), we have a combination of

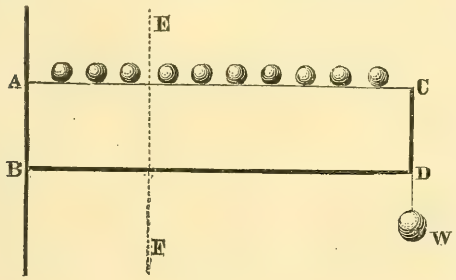

Fig. 17.

Cases I. and II. and the moment of the external forces at any section, E F, is

$$\tfrac{1}{2} wx^2 + Wx$$

Hence the equation of moments is

$$M = \frac{1}{6} S b d^2 = \tfrac{1}{2} wx^2 + Wx \qquad (15)$$

This is greatest at A, or

$$M_0 = \frac{1}{6} S b d^2 = \tfrac{1}{2} wl^2 + Wl \qquad (16)$$

The shearing force

$$T = wx + W \qquad (17)$$

At A

$$T_0 = wl + W \qquad (18)$$

Geometrically. The simplest way of representing the moments is to construct those due to each kind of weight, and then combine them. Thus, let $M' = \frac{wx^2}{2}$ and $M'' = Wx$. Construct M' as in *Case II.*, it being represented by a parabola with vertex at C and axis vertical, and M'' as in *Case I.*, it being represented by

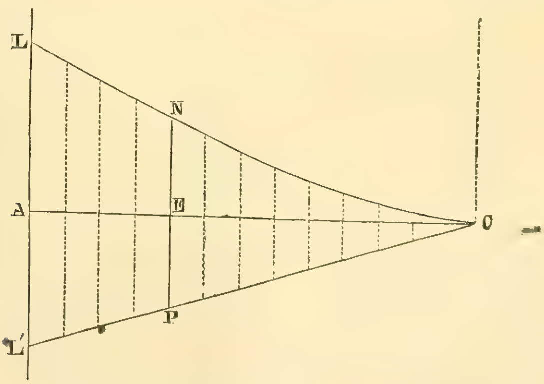

Fig. 18.

a triangle (placed under A C for convenience). Since $M = M' + M''$ from eq. (15) we have the total moment at any point E (Fig. 18) represented by the sum of the ordinates of these two figures=N P Fig. (18.)

The moments may also be represented by the parabola corresponding to eq.

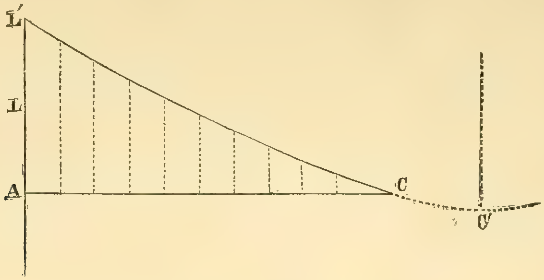

Fig. 19.

(15) as in Fig. (19.) This parabola has its vertex at C′ and not at C. Of course, only that part of the curve between C and A is applicable to our purpose.

The shearing force is represented by adding the triangle N P P′ Fig. (20) representing the variable part $w\,x$ of T to the rectangle C P which represents the constant part W of T.

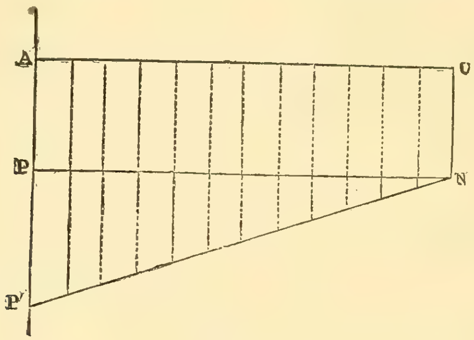

Fig. 20.

EXAMPLE.

Discuss the forces when the load is distributed as shown in Fig. (21) assuming various values for L N and N C as well as for w and W.

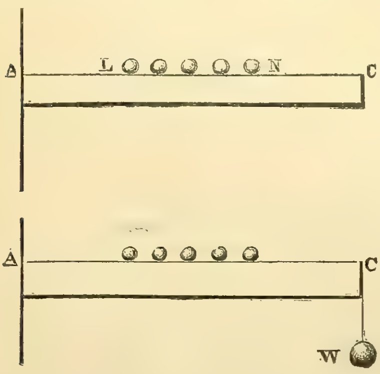

Fig. 21.

Case III.

Let the beam whose length is l rest upon supports at B and D (Fig. 22) and

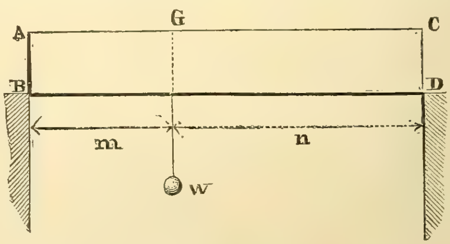

Fig. 22.

let it be loaded at some point G with a single weight W. Let m and n be the

segments into which the beam is divided at the point G of the application of the weight.

First find the proportions of the weight supported at B and D, or in other words, the reactions of the supports. By the principle of the lever the respective portions of the weight supported at B and D are inversely proportional to the distances of these points from G. Thus, let W'=reaction at D and W''=reaction at B and then

$$W' : W'' :: m : n$$
$$W''+W' : W' :: m+n : m$$

But $W'+W''=W$ and $m+n=l$

$$\left.\begin{array}{ll} \therefore & W'=\frac{m}{l}W \\ \text{And so} & W''=\frac{n}{l}W \end{array}\right\} \qquad (19)$$

Now apply the conditions of equilibrium to any part AE of the beam counting from A. Fig. (23).

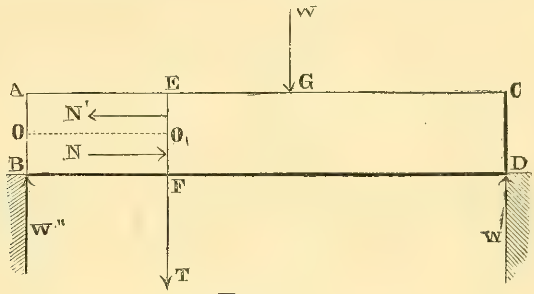

Fig. 23.

1st, Between A and G. $\Sigma X=0$ merely indicates the equality of N and N′, as these are the only horizontal forces. $\Sigma Y=0$ shows that the shearing force at the section EF is downwards

$$\text{and}=W'' \quad \therefore \quad T=W''=\frac{n}{l}W \qquad (20)$$

$\Sigma M=0$. The joint moment of N and N′ is as before$=\frac{1}{6}Sbd^2$. That of T is zero. The only other force acting on AE is W'', the reaction of the abutment. Let $OO_1=x$. Then the moment of W'' is

$$W''x=\frac{n}{l}.Wx$$

Hence $\quad \frac{n}{l}.Wx-\frac{1}{6}Sbd^2=0$

$$\therefore \frac{n}{l}Wx=\frac{1}{6}Sbd^2=M \quad (21)$$

2d, Between G and C (Fig. 24). Here,

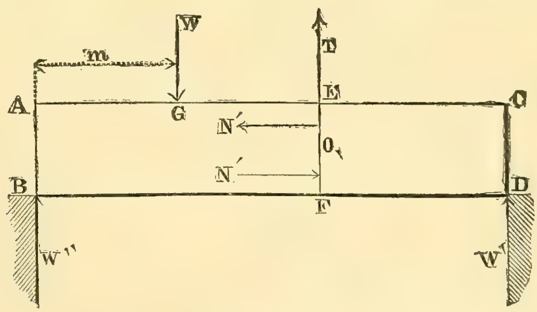

Fig. 24.

between A and E are the two external forces W'' at B and W at G. Hence the shearing force at EF is upwards and

$$T=W''-W=-W'=-\frac{m}{l}W. \qquad (22)$$

For $\Sigma M=0$ we have

$$-\frac{1}{6}Sbd^2+W''x-W(x-m)=0$$

$$\therefore \frac{n}{l}Wx-W(x-m)=\frac{1}{6}Sbd^2=M \quad (23)$$

The greatest value of eq. (21) is at G, where it becomes identical with eq. (23) for the same point. This value is

$$\frac{m.\,n}{l}\,\mathrm{W}=\frac{1}{6}\,\mathrm{S}\,b\,d^2=\mathrm{M}_0 \qquad (24)$$

At A and C the moments are zero.

Geometrically. From eq. (21), which is of the first degree, it is seen that the moments vary in A G as they did in *Case I.* Hence they may be represented by the ordinates of the triangle A L G. (Fig. 25).

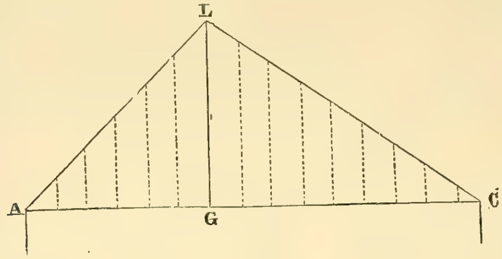

FIG. 25.

Eq. (23) is also that of a straight line cutting the axis of X at C. Hence the moments in G C are represented by the triangle G L C (Fig. 25). The shearing

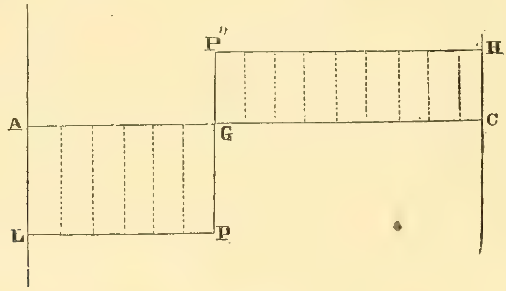

FIG. 26.

force in A G is represented by the rectangle A P and that in G C by the rectangle C P′.

Note, That the maximum moment (at G) corresponds to the point where the shearing force passes through zero.

Corollary 1. When the weight W is at the middle of the beam we have

$$n=m=\tfrac{1}{2}\,l$$

$$\mathrm{W}'=\mathrm{W}''=\tfrac{1}{2}\,\mathrm{W}$$

Then eq. (21) becomes

$$\tfrac{1}{2}\,\mathrm{W}\,x=\frac{1}{6}\,\mathrm{S}\,b\,d^2=\mathrm{M}$$

and (24) is

$$\tfrac{1}{2}\,\mathrm{W}\,(l-x)=\frac{1}{6}\,\mathrm{S}\,b\,d^2=\mathrm{M} \qquad (25)$$

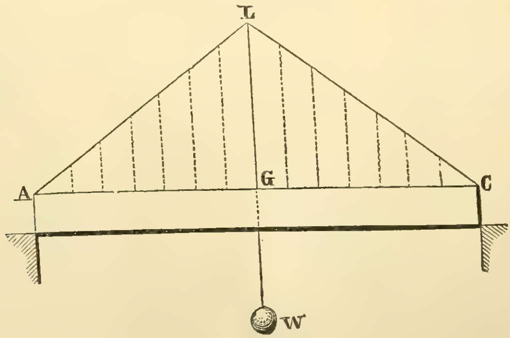

FIG. 27.

At the centre $M_0=\frac{1}{2}W.\frac{1}{2}l=\frac{1}{4}Wl$ (26)

The triangles A L G and G L C (Fig, 27) represent the moments in this case. G L having been laid off $=\frac{1}{4}Wl$.

The shearing force throughout the beam is then $T=\frac{1}{2}W$ (27) as is shown in the rectangles (Fig. 28).

Comparing the value of M_0 given in

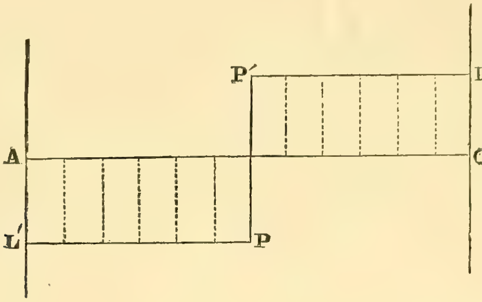

FIG. 28.

eq. (5) *Case I.* with that of M_0 in eq. (26) we see that the load and the length being the same, a beam will bear *four* times as much with both ends supported, and the load placed in the middle as it will do with one end fixed and the other loaded.

Corollary 2. When there are several weights, as in Fig (29), the moment of the external forces at any section is that

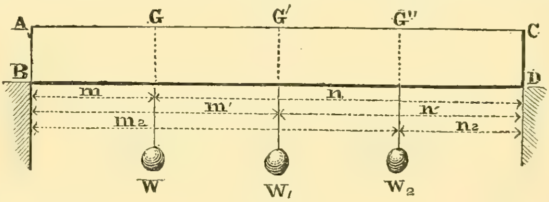

FIG. 29.

due to the action of all the weights. Let the segments into which the weights W, W_1 and W_2 divide the beam be m and n for W, m_1 and n_1 for W_1 and m_2 and n_2 for W_2.

Let R_1=reaction of abutment at B and
R_2=reaction of abutment at D and
l=length and let x be counted from A as before.

The reaction of the abutment at B due to these weights is

$$\left.\begin{aligned} R_1&=\frac{n}{l}W+\frac{n_1}{l}W_1+\frac{n_2}{l}W_2 \\ \text{So at D } R_2&=\frac{m}{l}W+\frac{m_1}{l}W_1+\frac{m_2}{l}W_2 \end{aligned}\right\} (28)$$

For any section between A and G, R_1 is the only external force and hence the equation of moments is

$$R_1x=\frac{1}{6}Sbd^2=M \qquad (29)$$

The shearing force is $\quad T=R_1 \quad$ (30)

For every section between G and G′ the weight W is to be taken into consideration and the equations are:

$$R_1x-W(x-m)=\frac{1}{6}Sbd^2=M \qquad (31)$$

$$T=R_1-W \qquad (32)$$

For any section between G′ and G″) we have:

(33)

$$R_1x-W(x-m)-W_1(x-m_1)=\frac{1}{6}Sbd^2=M$$
$$T=R_1-W-W_1$$

For any section between G″ and C

$$\left.\begin{aligned} R_1x-W(x-m)-W_1(x-m_1)-W_2 \\ (x-m_2)=\frac{1}{6}Sbd^2=M \\ T=R_1-W-W_1-W_2 \end{aligned}\right\} (34)$$

The location of the greatest moment

is most readily determined by geometrical construction.

Geometrically. The moments are represented in Fig. (30) by constructing separately those due to each weight and then combining them. Thus, the moments produced at every point in the beam by the weight W are represented

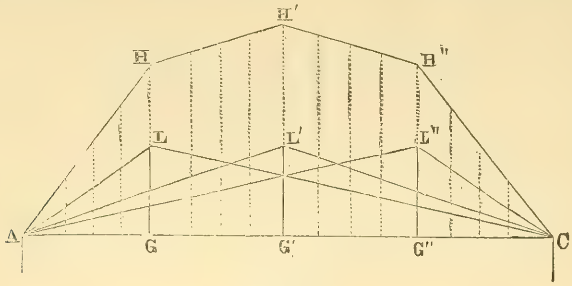

Fig. 30.

by the triangle A L C (Fig. 30), in which G L equals the greatest moment due to $W\frac{n}{l}Wx$. Similarly A L′ C represents those due to W_1, G′ L′ being$=\frac{n_1}{l}W_1x$, and A L″ C gives those due to W_2, G″ L″ being$=\frac{n_2}{l}W_2x$.

Now, if at every point we add together the ordinates of these three triangles for that point, and lay them off above A C we shall get a polygon A H H′ H″ C, which represents eqs. (29) (31) (33) and (34) and gives the total moment at any section. The greatest ordinate of this polygon will, of course, show the location of the maximum moment. This will be at G or G′ or G″, according to the relative amounts and positions of the weights W, W_1, and W_2. In the fig. it is at G′. Hence from eq. (31)

$$R_1\,m_1-W(m_1-m)=\frac{1}{6}\,S\,b\,d^2=M_0 \quad (35)$$

The shearing force may be represented as in Fig. (31). It is greatest in that

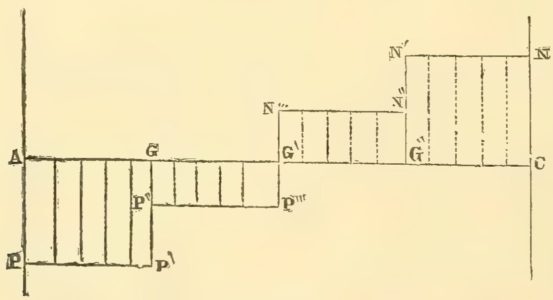

Fig. 31.

one of the two end segments which corresponds to the greater of the two quantities R_1 and R_2.

Note, That in this case the simplest way of finding the point of maximum moment is to construct the figure representing the shearing force, and the point when the shearing force passes through zero (G′ Fig. 31) is the point sought.

EXAMPLES.

1. Let l=20 ft. m=5 ft. m_1=10 ft. m_2=15 ft. W=1 ton W_1=2 tons W_2=3 tons.

Find the maximum moment.

2. Find the size of a rectangular wooden beam where

l=15 ft. m=3 ft. m_1=6 ft. m_2=14 ft.
W=1 ton $W_1=\frac{1}{2}$ ton W_2=2 tons
S=1,000 lbs. and $d=4\,b$.

EXTRACTION OF THE PRECIOUS METALS CONTAINED IN COPPER PYRITES.

Translated from the French of F. CLAUDET,* by ED. DAVID HEARN.

From the "Mining Journal."

SULPHURIC acid, which occupies a prominent position among the chemical products employed in industrial pursuits, was long made almost exclusively from the sulphurs of Sicily; but on the one hand fiscal measures which interfered with their exportation, and on the other the progressive increase in the consumption of sulphuric acid, led the manufacturers to substitute for sulphur the pyrites which is found in almost all countries. It is from Spain and Portugal that the English manufacturers draw the greater part of the pyrites which they use, and as they are more or less cupriferous, the residuum after the extraction of the sulphur was principally sold to the copper smelters, who, owing to oxide of iron constituting the greater part of the residuum, employed it as flux for the smelting of quartzose copper ore; in this operation the copper in the pyrites was recovered, but naturally all the iron was lost in the slag. The extraction of copper from its ores by the wet way, first practiced by Mr. Longmaid, then applied by Mr. W. Henderson to the pyrites of Spain and Portugal, no longer caused this loss of iron; this process has been largely developed, resulting in a constant increase in the importation of pyrites, which now reaches to from 400,000 to 500,000 tons per year, and goes on increasing. The pyrites sells according to its produce for sulphur and for copper; manufacturers who only buy it for te sulphur re-sell the burnt ore to works in which the copper is extracted. It is a work of this kind that I and Mr. J. A. Phillips, both graduates of the School of Mines of Paris, have established at Widnes, near Liverpool. The pyrites of Spain and Portugal is composed (the proportions only varying within very small limits) of the different elements of which the following analysis will give an example; it is that of a sample from the San Domingo Mines from the working of which, ably developed by Mr. J. Mason, about one-half of the pyrites are supplied.

Sulphur	49.00
Arsenic	0.47
Iron	43.55
Copper	3.20
Zinc	0.35
Lead	0.93
Lime	0.10
Water	0.70
Quartzose residue	0.63
Oxygen and Loss	1.07
	100.00

In the last item of 1.07 traces of a large number of metals are found. This pyrites, after having been burnt for the manufacture of sulphuric acid, is the material which is treated for the extraction of the copper; it then contains, with but slight variation:—

Sulphur	3.76	
Arsenic	0.25	peroxide.
Iron	58.25=	83.00
Copper	4.14	
Zinc	0.37	
Cobalt		Traces.
Silver		Traces.
Lead	1.14	
Lime	0.25	
Insoluble residue	1.06	
Water	3.85	
Oxygen and loss	26.93	
	100.00	

As to the silver which is only mentioned as "traces," it is very difficult to assay it precisely in this kind of ore; however, the numerous assays that I have made have enabled me to estimate the quantity between 0.0020 and 0.0028, or from 20 to 28 grammes to the ton. But small though this proportion may be, I did not doubt that we could succeed in extracting it with profit, and this I have done by a process allied to that of the extraction of copper by the wet way, a short description of which I will now give:—We commence by stamping and washing the residue of the pyrites, then they are roasted with chloride of

* "Nouveau Procédé pour l'Extraction des Métaux Précieux contenus dans les Pyrites Cuivreuses." Par F. CLAUDET, Présente á l'Academie des Sciences. Paris, Hennuyer.

sodium in a reverberatory furnace at a very low temperature; the oxidation of the metallic sulphides and the decomposition of the chloride of sodium which follows give rise to the formation of sulphate of soda and soluble chloride of copper. When we are satisfied by trial of samples that the ore has been properly roasted it is taken out of the furnace, and when it has sufficiently cooled it is thrown in to about three-fourths fill a large wooden tank, with a double bottom forming a filter, and is washed with several waters slightly acidulated with hydrochloric acid until the copper is taken up. There remain in the tank the insoluble portions which consist almost entirely of oxide of iron, and of which the subjoined analysis will give an example:—

Peroxide of iron...	96.20=67.35 metallic iron.
Lead, as sulphate..	0.86
Copper............	0.18
Cobalt..................	Traces.
Alumina..........	0.45
Lime.............	0.46
Soda.............	0.10
Phosphoric acid.........	No traces.
Arsenic acid.............	Traces.
Sulphuric Acid...	0.49
Sulphur..........	0.16
Chlorine..........	0.03
Silica.............	1.22=100.15.

This oxide of iron in consequence of its uniform composition and fine state of division, is sold to the iron manufacturers, who use it with advantage for fettling the puddling furnaces.

Returning to the mother liquid from which the copper has to be extracted, it is run into other tanks, in which fragments of iron, such as scrap iron, have been placed; chloride of iron is formed, and the copper is thrown down, taking with it the small quantity of silver of the ore which was dissolved in the liquor. The copper precipitate is then melted and refined to bring it to the state of marketable copper. In the water from which the copper has been separated there are also found salts of iron mixed with alkaline salts which are not acted upon, but by subsequent operations we have been able in our works to obtain, and profitably, too, on the one hand, sulphate of soda in a state of almost absolute purity, and on the other, oxide of iron in so fine a state of division that it is applicable to the polishing of looking-glasses. The waters before the precipitation of the copper by the iron contains, as we mentioned, the silver of the ore dissolved in the state of chloride; to extract it we first naturally think of precipitating it by metallic copper, but silver, being soluble in a mixture of chloride of sodium and deutochloride of copper, the precipitation cannot take place so long as all the deutochloride is not converted by the metallic copper into a protochloride, and then the small quantity of silver is probably found precipitated with the copper in excess, and also with the protochloride of copper which the chloride of sodium is no longer sufficient to dissolve. We must then have recourse to a fresh process of separation, and the expense of this complicated operation absorbs more than the value of the silver; the process then is not commercial. There is another means of separating the silver from the copper, which consists in making a sulphate of copper of the precipitate; but the great aim in the treatment of the mineral is the production of metallic copper, and not sulphate of copper, the consumption of which is very limited, so that the process is only applicable within narrow limit.

I had then to seek another mode of separation, and I succeeded, after numerous trials, to discover and put in practice a process which I will now describe; it is founded on the fact that iodide of silver is almost entirely insoluble in a solution of chloride of sodium at the ordinary temperature. The ore roasted with common salt undergoes, as we have said, several washings, yet but little else than the three first waters contain a sufficient quantity of silver to be worth treating. We have ascertained by experiment that the two first waters contain 83 per cent. and the three first waters 95 per cent. of all the silver dissolved. According to the analysis of one of these waters, marking 1.24 of the ærometer, a cubic metre of this liquor contained:

Sulphate of soda....Kilos.	144.171
Chloride of sodium........	63.914
Chlorine in combination with metals...	66.143
Copper	52.855
Zinc.....................	6.857
Lead.....................	0.571
Iron.....................	0.457
Lime.....................	0.743
Silver...	0.0437=335.7547

We have neglected in this analysis the small quantities of arsenic, bismuth, &c. This result is only given by way of example, for the silver which we quote 43.7 grammes varies in our operations from 25 to 27 grammes per cubic metre, according to the richness of the mineral and the degree of concentration of the liquor. It is then the water from the three first washings only that we use. We run them into a wooden tank, where they are left to settle, so that solid matters held in suspension may separate, and, in order not to employ more iodide of potassium than is absolutely necessary, we first assay the silver contained in the liquor. For this purpose we take a fixed measure of it, dilute it with water, adding a little hydrochloric acid, to keep all the copper in solution; then we pour in a few drops of a weak solution of iodide of potassium, which changes the soluble chloride of silver into the insoluble iodide of silver at the same time that by the addition of a solution of acetate of lead we cause the formation of a strong plombiferous precipitate, which contains all the silver. This precipitate is dried, and then melted with a flux to which metallic iron is added; the resulting argentiferous lead is cupelled, and from the weight of the button of silver the quantity contained in the liquor is determined.

The clear titrated liquor is then passed into another tank, and the quantity of iodide of potassium found to be necessary by the assay is added, and it is diluted with a quantity of water equal to about a tenth of that of the cupreous liquor; the whole of the liquor is then shaken and left to settle for 48 hours; the supernatant liquor is then clear; it is drawn off, and the tank is refilled for repeating the operation, and so on.*

Once a fortnight we collect all the deposit which has accumulated; it is principally composed of sulphate of lead, iodide of silver, and salts of copper. These latter are readily separated by washing with weak hydrochloric acid. The deposit, cleansed from the salts of copper, is decomposed with metallic zinc, which in the presence of water rapidly and completely reduces the silver by uniting with the iodine, and forming soluble iodide of zinc. There is thus produced—1. Soluble iodide of zinc, which, separated by filtration, is titrated, and used as a substitute for the iodide of potassium in subsequent operations to precipitate fresh quantities of silver.—2. A deposit rich in silver, composed in a great part of lead in the metallic state, and as a sulphate containing besides various substances, of which the subjoined analysis of a dried sample may be given as an example:

Silver	5.95
Gold	0.06
Lead	62.28
Copper	0.60
Oxide of zinc	15.46
Oxide of iron	1.50
Lime	1.10
Sulphuric acid	7.68
Insoluble residue	1.75
Oxygen, and loss	3.62=100.00

This analysis shows that all the iodine of the iodide of silver has entered into combination with the zinc, and re-become soluble, since the deposit contains none or only traces. Gold, which has not before been mentioned, appears here for the first time, and we may ask how this happens? It exists then in the ore, and it would appear that in the operation of roasting it forms chloride of gold, which, rendered more stable by the presence of chloride of sodium, is not reduced at the low temperature of the roasting; it then enters into solution with the silver, and, like it, it is precipitated by the iodine. It is now easy to separate from this product the precious metals by the ordinary processes employed by smelters who treat gold and silver matters. It will, no doubt, be interesting to know the results we have obtained by the application of the process during a year. The process was applied in 1871 (the paper was read in 1872) to 16,300 tons of burnt pyrites, from which we extracted of silver 333.242 kilos., and of gold 3.172 kilos., representing a little more than 20 grammes of the precious metal per ton, and producing £3,232 after deducting the cost of melting and refining. The expenditure directly connected with the precious metals amounted to £416, which includes the cost of 137 kilos. of iodine, representing the loss of that material,

* These liquors, which are drawn off, still contain a small proportion of silver in solution, about 5 grammes per cubic metre, for, as we have mentioned, the iodide of silver is not absolutely insoluble in these liquors. It is scarcely necessary to add that they re-enter again in the ordinary working for the extraction of the copper.

and 1,900 kilos. of zinc, and it is remarkable that the gold which exists in the ore in appreciable quantity suffices to cover the whole cost of the process. The cost of the iodine, already large, has become much more considerable through the abnormal increase in the price of the product, and has called my attention to the direct employment that might be made of the lye from the ashes of seaweeds instead of iodide of potassium. The recent experiments we have made in this direction have answered my expectations, and not only have we succeeded in utilizing by this means all the iodine contained in the seaweed, and great part of which is, as we know, at present lost, but the trials have suggested to me the idea of an inverse operation, to which I am now giving attention, for making iodine, and which consists in precipitating this metalloid from the seaweed lye by means of a salt of silver. This extraction of 20 grammes of precious metal from the ton of burnt pyrites is, I admit, not very considerable; but when we consider that the process could be applied to 350,000 tons of ore, and thus produce, with a good profit, too, 7,200 kilos. of the precious metals, of the value of £68,000, it will be seen that it is an annual result not to be neglected.

This process can also be employed for various other copper ores susceptible of treatment by the wet way, and we have begun to apply it to the copper ores of Cornwall, which generally contain more silver than the Spanish pyrites, and which hitherto have been worked by the dry way, and solely for the extraction of the copper. The results which we have just recorded show how highly important it is, in metallurgical operations, to deal with large masses; we thus obtain profits where the same process applied to limited quantities could only result in loss. We will make the further remark upon this subject that large quantities of the precious metals have been lost, and are still lost daily, in metallurgic operations, and we do not doubt that many of the residues in various parts of the globe which have been neglected as too poor will one day be re-treated to separate the gold and silver which they contain.

THE DRAINAGE OF CALCUTTA.

From "The Builder."

Ten years ago Sir John Strachey declared that the capital of British India was "a scandal and a disgrace to a civilized Government," and asserted that it was literally unfit for the habitation of civilized men. He declared that the most important streets and thoroughfares of the northern division of the city formed to all intents and purposes a series of huge public latrines, the abomination of which could not be adequately described. And he vehemently added, the other cities and towns of India were almost faultless when compared with the metropolis. Yet at that time sanitary questions were altogether unknown in India, and Miss Nightingale had reported that no one of the presidential cities of India had arrived at that degree of civilization in their sanitary arrangements which the worst parts of our worst towns had reached before healthy reform in such matters sprang up in England at all. This reproach has now been wiped away from the Indian capital, and there are signs that Bombay and Madras will soon be rendered salubrious. At Norwich, in November last, Miss Nightingale was able to state that "the drainage of Calcutta bids fair to be a wonder of the world, and said that the city had become more healthful than Manchester or Liverpool, and might even be considered a *sanitarium* compared with Vienna or Berlin." How has the change been accomplished?

Calcutta lies in close proximity to a vast stagnant marsh, known as the Salt Water Lake. Even in its infancy the settlement was unhealthy, and as it grew in size its insalubrity increased. Cholera continually haunted it, fevers and dysentery made it their home, and when it had come to be termed the City of Palaces, it was equally well known as the City of Pestilence. But the traders

who frequented its bazaars risked their health for the sake of the rupees which flowed into their coffers; the servants and officers of John Company had too many wars on hand, and too many States to annex, to pay much heed to the healthiness of the town, and to the soldiery the chances of death on the field or under the friendly guns of Fort William were about the same. But at length the mortality of Calcutta became so notorious that the Government could no longer overlook it, and a committee was appointed to inquire into the causes of the prevalence of perennial fever, and to propose remedial measures. This committee sat for several years previously to 1840, amassed a great amount of repulsive evidence, and in the end proposed the establishment of a fever hospital. The Medical College Hospital was accordingly founded ; but while it afforded relief to the afflicted, and did save a few lives, such a solitary institution could not materially diminish the death-rate. At that time, and for many years afterwards, the affairs of the city were managed by a Conservancy Board, composed of two European and two native commissioners; but although these gentlemen were anxious to do their duty, they lacked professional skill to direct their efforts, and wasted their energies in futile projects. The night soil was collected from house to house by scavengers, and conveyed in open carts to the river, into which it was thrown at a point above the harbor. The stable refuse and house rubbish were shot into the streets and road-ways, and subsequently carted away to fill up disused tanks and ponds, and to raise the foreshore of the river ; while the surface water of the thoroughfares and compounds, the slops from the houses, including urine, and the storm water were allowed to find their way by surface gutters into the Hooghly and into the Circular Canal—a deep cutting which almost surrounds Calcutta to the eastward. The whole subsoil of the city was saturated with filth which had spread from innumerable cesspools, and with water which had percolated through from the Hooghly, or had fallen during the monsoons. Only vile drinking-water was needed to render the Indian capital the permanent abode of plague and pestilence—and this was also provided; for wells and the river alike were impregnated with sewage matter. In the tropics with so much of the results of decomposition in air, earth, and water, it is surprising that life was at all endurable, and that the people submitted to the nuisance so long. But although the European inhabitants grumbled, the native Commissioners opposed all schemes for extensive reform; and affairs rolled on on the filthy old groove until, in 1855, Sir Frederick Halliday was appointed to the new office of Lieutenant-Governor of Bengal. An administrator so able at once detected the foul spot, and succeeded in convincing the Commissioners that they were personally incapable of superintending the work of reform. By his advice a professional adviser was called in, and Mr. William Clark, C. E., was appointed to the post. In the following year that gentleman submitted a scheme, with estimates attached, for the drainage of the city, and a committee was appointed to report upon it. After deliberations extending over eighteen months, the committee reported favorably upon the project, and it was sent on with their endorsement to the Government. To make assurance doubly sure, the plans, about which little difference of opinion then existed, were handed over for supervision to Mr. Rendel, C. E., who happened to be in India at the time. By him they were carried to England; but after considering them for ten months he reported unfavorably with regard to them, and proposed a counter scheme of his own. Then the mutiny broke out; people had other work to do ; and the whole affair was shelved for a time. However, when the rebellion had been suppressed the Government at an early date returned to its previous intentions, the rival projects were compared; the proposals of Mr. Clark were preferred, and orders were given to begin the work. It was in 1859 that the undertaking was commenced, and it is not quite complete now.

Mr. Clark's scheme comprised outfall works and large brick sewers in every part of the town, which lay within 1,000 feet of the main drainage lines, leaving minor pipe sewers for future consideration. The large sewers, five in number, and varying from 6 feet to 8 feet in

height, extended from the river to the east at right angles across the town; and these sewers were connected at their eastern extremity by an $8\frac{1}{2}$ feet sewer placed beneath what is known as the Circular Road. From the middle of this road the outfall branched off in a due easterly direction in the bed of what was formerly the Entally Canal, which, being useless, was filled up for the purpose. The outfall sewer, 16 feet high, was continued to a length of 3,284 feet, to a channel cut in the marsh or salt water lake before referred to, and thence it is eventually to be conducted to a distance of ten miles from the city, and there discharged into the tidal stream of Sunderbund. From the river, eastward, the level of the surface of the land falls at the rate of 3 feet per mile, and eventually forms the Salt Water Lake. The waters of the Hooghly can thus be utilized at discretion, in flushing the sewers during the dry season; while, at other times, the storm water can be discharged into the river at low tide.

The perfection of the drainage scheme necessarily involved one for water supply. Accordingly, Mr. Clark proposed to take water from the Hooghly, seventeen miles above Calcutta, pump it into large settling reservoirs, filter it, and pass it down to the city in iron mains, 42 inches in diameter. Thence it was meant to pump it during the night into a large reservoir in the centre of the town, from which it could be pumped for distribution during the following day. This project was sanctioned in 1865; the works were commenced at the end of 1866, and were completed in three years. The daily delivery is about eight million gallons for a population of about 500,000 inhabitants. It is distributed under a pressure of 50 feet by engines fixed near the central reservoir. Stand-posts are fixed in the streets for supplying the poorer classes, while house-pipes may be connected with the mains if it be so desired. The cost of these works was about £600,000, which was advanced by the Government to the Municipality at $4\frac{1}{2}$ per cent. After having served domestic purposes the eight million gallons of water are discharged into the sewers by the drains; this water flows by gravitation, with the subsoil water and the light shower water, to the pumping-station, where it is disposed of as described. The sewers are divided into three classes. First, the large ones branching off from the river to the Circular Road, and ultimately to the pumping-station. There are ten miles and three-quarters of this sort. The second-class are also brick sewers from 3 feet to 5 feet high, and are laid along the principal streets at right angles to those of the first-class. These sewers are twenty-three miles long, and both these and those of the first-class are finished. The third-class, which will drain the narrow lanes and the interior of the blocks of buildings surrounded by the first and second-class, will consist of stoneware piping. They also are very nearly complete, and their total length is estimated at seventy-nine miles. Thus, when the whole network is finished there will be 113 miles of sewers, which represent the road mileage of the city.

Considerable difficulties attended the execution of the scheme, and there were some differences of opinion as to the mode of carrying it out, but they were overcome, one after another. Native bricks were employed; a large brick-making establishment was set on foot at a place nine miles above Calcutta, and the native brickmakers soon succeeded in producing, with their simple apparatus, bricks as good as, and less expensive than, those turned out by the European machines which had been imported. For many years the brickfield had produced about 8,000,000 of hand-made bricks. As brick-dust, or what is known locally as "soorkie," is employed instead of sand with lime in making mortar, about 500 maunds of it were supplied every day. Stoneware pipes, varying from 6 inches to 12 inches in diameter, were supplied from Doulton's potteries at Lambeth; and when laid down the lowermost half of the openings was united by cement, and the upper half by puddled clay, through which the subsoil water was permitted to percolate. The saturated subsoil was a great obstruction to progress. A trench, dry overnight, would be found to be more than half full of water in the morning; and no amount of pumping was equal to the task of keeping the trenches dry enough. After many abortive attempts, Mr. Clark adopted the plan that has been fol-

lowed in London of laying a stoneware pipe at the bottom of the trench, and covering it with a bed of concrete, upon which the brick sewer was built. The lowermost part of the inner circumference of the sewer was coated with Portland cement, and made water tight, but the other half was unprotected. The walls varied according to the size of the sewers from 5 inches to 20 inches of brick-work in rings. The subsoil water enters the sewers either at the bottom, by means either of the small stoneware pipe or by percolation through the upper half of the brickwork ; and the plan has been so successful that its level has been reduced by 7 feet or 8 feet. The sewers are employed to remove the subsoil water, the drainage of the houses, and the rain water. In a tropical country, the rainfall is a most important consideration, that of Calcutta varying from 75 inches to 90 inches per annum. Hence the sewers had to be made of exceptionally large size, and it is said they can take the equivalent of a quarter of an inch of rain per hour, which, if collected, would be represented by a running-stream 40 feet wide, 8 feet deep, and flowing at a velocity of 4 feet per second.

During the monsoons, when the storm-water falls in sufficient quantities to over-power the pumps at the pumping-stations, it is discharged by special outlets into the Circular Canal, adjoining the Circular Road, whence it flows off into the natural streams of the country eastward. It is admitted into the sewers by gully-gratings placed at the sides of the footpaths, which gratings cover a deep pit provided to intercept the road grit, which is removed by manual labor. Such of the grit as finds its way along the sewers to the pumping-stations is intercepted there. The stable-litter, kitchen-stuff, and other more solid refuse of the town are removed from every house by municipal carts daily to a railway that runs along the Circular Road, carried by it to the Salt Water Lake, and there deposited. There have been various proposals for utilizing the sewage-matter and litter at the place of their deposit, but no action has yet been taken, atlthough it is very unlikely that such a profitable deposit will remain long without being turned to good account.

The Calcutta justices are empowered to compel householders to connect their premises by suitable drains with the public sewers, but they are reluctant to enforce their authority, and prefer leaving every man to his own discretion. It is very questionable whether their laxity is to be commended, for much of their outlay is thereby rendered unproductive, and the health of the whole city suffers. The city death-rate, however, has been reduced by more than one half. When the public sewers are not used the householders allow the drainage of their dwellings to gravitate into cesspools and ditches, and it is only when they have become an intolerable nuisance and a source of pestiferous exhalation which cannot be endured that they are cleaned out, and the contents, in a state of active decomposition, are carted away and shot into the sewers. It is gratifying, however, to state that the natives are beginning of their own accord to appreciate the advantages of the public sewers, and to understand the dangers attendant upon the accumulations of filth, within and about their dwellings. Hitherto the cost of connections and other private drainage works has acted as a deterrent to the smaller owners and holders. Recently, however, a shrewd native justice suggested that the English system should be adopted, by which such persons can have their premises drained by the municipal authorities, and pay off the combined interest and cost at a fixed annual rate. The project has been adopted, and it is anticipated will become popular.

The total cost of the drainage works of Calcutta, when completed, will be about £800,000, of which nearly £600,000 have already been expended. The money has been raised partly by municipal debentures bearing 6 per cent. interest, and latterly by a Government loan. The benefits, however, amply compensate for all the expenditure.

New Signaling Apparatus.—Mr. W. Leach, of Wigan, has patented an invention which relates to the construction of a signal apparatus for collieries, mines, and other underground works, the object being to combine visible and audible signals from the persons at the bottom of the shaft to the engineer at the pit mouth, such signals remaining visible until the engine has commenced to wind up, and then returning automatically to zero.

REPORTS OF ENGINEERING SOCIETIES.

King's College Engineering Society.—At a meeting of this society, held on June 11th, Mr. E. L. Hesketh, A.K.C., read a paper on some experiments in centrifugal pumps, made at the works of Messrs. Easton and Anderson, of Eirth. The author commenced by describing the pumps which were experimented with. The first was a 10 in. pump with trunk engine attached, and the second was a vertical spindle pump with 2ft 6in. fan. He described the way in which the experiments were conducted, and also the method of finding the throw. The best results were obtained when the case was made of a spiral form inside by the temporary introduction of a curved piece of wood. A pump is now being constructed which will have the case cast in a spiral form. In the other pump two other forms of fan were used, viz., Rankine's and the involute. The latter gave by far the best results, but still not satisfactory, as the water rotated inside the pump at such a rate, but the notion was conceived of having curved blades placed in such a position as to utilise the rotary motion of the water and convert it into a vertical one. The paper was illustrated by several diagrams, photographs, and models.

IRON AND STEEL NOTES.

Brightening Iron.—A Bavarian serial contains a method of brightening iron recommended by Boden. The articles to be brightened are, when taken from the forge or the rolls, in the case of such articles as plates, wire, &c., placed in dilute sulphuric acid (1 to 20), where they remain for about an hour. This has the effect of cleansing the articles, which are then washed clean with water and dried with sawdust. They are then dipped for a second or so in nitrous acid, washed carefully, dried in sawdust, and rubbed clean. It is said that iron goods thus treated acquire a bright surface, having a white glance, without undergoing any of the usual polishing operations. This is a process that those interested can easily test for themselves, but care should be taken with the nitrous acid not to inhale any of its fumes. Boden states that the action of the sulphuric acid is increased by the addition of a little carbolic acid, but it is difficult to see what effect this can have, and it may very well be dispensed with.—*English Mechanic.*

The Danks Furnace in America.—Information of a later date than Mr. I. L. Bell's visit to the United States has been received in Staffordshire relative to the working of the Danks furnace in the States. The ex-president of the Iron and Steel Institute in his "Notes of a Visit to Coal and Iron Mines and Ironworks in the United States," said that two establishments at which the Dank system was still in use were the Railroad Mill at Cincinnati, under the personal superintendence of Mr. Danks, and the Mill of Messrs. Graff, Bennett & Co., of Pittsburgh. Mr. Bennett and his Manager—Mr. Williams—Mr. Bell declared to be equally sanguine with Mr. Danks as to the ultimate success of the system. The later information is that Messrs. Graff, Bennett & Co. are increasing their number of furnaces, that they are taking the bloom direct to the Universal Rolling Mill—which has reverse motion—and that upon coming out of the rolls the hot iron is slit to varied widths by powerful cutters. When the Danks process was discussed by the Staffordshire mill and forge managers, on the occasion of their visit to the Ravensdale Works in North Staffordshire, certain of them expressed doubt as to the practicability of dealing with such large blooms as were produced by the rotary furnace, so as to make from them the smaller sizes of finished iron for which South Staffordshire is best known; and it was pointed out that the difficulty might be met by slitting the blooms immediately they left the forge rolls. It would seem as though Messrs. Graff, Bennett & Co. are leading the way in an adaptation of the Danks process to the making of the smaller sizes. If they are successful in this work, what they are doing is of considerable importance to South Staffordshire. Though nothing is known of any present attempt to lay down the Danks plant in South Staffordshire, yet there is a rumor that, at least in one instance, there is a disposition to test the Crampton furnace. Nevertheless, the probability that one or the other, or it may be both, will be forced upon the district at no distant day is pretty generally conceded.—*Engineer.*

Production of Pig Iron in the United States in 1874.—The American Iron and Steel Association has received from the producers and from its correspondents full statistics of the production of pig iron in the United States in 1874. The total production was 2,689,413 net tons, against 2,868,278 net tons in 1873, and 2,854,558 net tons in 1872, showing a decrease of 178,865 tons as compared with 1873, and 165,145 tons as compared with 1872. Notwithstanding this decrease, the production in 1874 was much larger than was generally anticipated—much larger even than partial returns made to the Association at the close of 1874 indicated. This unexpected result is, however, susceptible of a satisfactory explanation. As preliminary to this explanation we give the following statistical resume:

Years.	No. of furnaces Jan. 1st.	No. of furnaces built during the year.	Total number of furnaces Dec. 31st.	Out of blast Dec. 31st.	In blast Dec. 31st.	Production of pig iron in net tons.
1872..	574*	41	615	115¶	500	2,854,558
1873..	615	50	665	252	413	2,868,278
1874..	665†	38	701	336	365	2,689,413

* Including 3 spiegeleisen furnaces in New Jersey.

† Two furnaces were abandoned in 1874.

¶ Estimated.

On the 1st of February, 1874, of 701 completed furnace stacks in the country, there were in blast 303 stacks and out of blast 398 stacks. Sixty-two furnaces were blown out in January. These figures indicate the lowest degree of depression reached since the panic up to that date. Since February 1st the number of furnaces *out of blast* has been slightly increased.

The number of new furnaces completed in 1874 was 38, against 50 in 1873 and 41 in 1872. The astonishing number of 46 stacks is reported to us as being in course of erection in 1875, while other new furnaces are projected.

The following States made more iron in 1874 than in 1873: Maine, Vermont, Massachusetts, New York, Virginia, Georgia, Alabama, Texas, West Virginia, Tennessee, Ohio, and Michigan. The following States made less iron in 1874 than in 1873: Connecticut, New Jersey, Pennsylvania, Maryland, North Carolina, Kentucky, Indiana, Illinois, Wisconsin, and Missouri. The district showing the greatest increase during 1874 was the Miscellaneous bituminous coal and coke district in Ohio. The district showing the greatest decrease during 1874 was the Lehigh anthracite district in Pennsylvania.

Utah Territory made her first pig iron in 1874—200 tons of charcoal. After a long rest Oregon, with one furnace, made 2,500 tons of charcoal iron in 1874. Texas made 1,012 tons of charcoal iron in 1874. South Carolina, with eight furnaces, and Minnesota, with one furnace, made no iron in that year.

The production of charcoal pig iron in 1874 was within 1,903 net tons as large as that of 1873, being 572,817 net tons in 1874 against 574,720 tons in 1873.

The total imports of pig iron into the United States in 1874 were 61,165 net tons, against 154,708 net tons in 1873, 295,967 net tons in 1872, and 245,535 net tons in 1871.

The total exports of pig iron from the United States to all countries in 1874 were 16,039 net tons, against 10,104 net tons in 1873, and 1,477 net tons in 1872.—*Abstract from the Bulletin.*

RAILWAY NOTES.

Enormous Engines.—An engine has recently been placed on the Pennsylvania Railroad which weighs seven tons heavier than the ponderous Modoc, whose drawing capacity is almost twice that of an ordinary locomotive. The Modoc is capable of taking eighty loaded cars from Harrisburg to Columbia, while other engines are put to a severe test when they pull fifty cars on that portion of the road. The new locomotive when fully initiated is expected to get away with a hundred cars. The only argument that can be used against large engines is that they are hard on tracks, but as the Pennsylvania Railroad Company has adopted steel rails—able to withstand a far greater pressure than iron rails—the wear will not be material. The introduction of these mammoth engines is considered a very economical measure by the railroad company.—*Iron World.*

The total length of railways thrown open to traffic in Russia during 1874, may be taken as 1160 English miles. The total railway mileage of Russia, including Finland, represented 11,576 English miles on the 1st of January, 1875, which length very nearly coincided with the French railway mileage on the 1st of January, 1874, France showing then a total corresponding mileage of 18,565 kilometres, or 11,510 English miles. At the present time Russia is engaged upon the fourth section of the Losowaja-Seevastopol railway, the Rostow-Wladikawkas line, the Kornescty-Pruhtbridge line, the Fastow-Snamenka line, the Orenburg Railway, the Ural line, and the Vistula Railway.

Three years' experience on the Denver and Rio Grande 3ft. 6in. road has determined the fact that much wider cars can be run with safety than was at first supposed possible on so narrow a gauge. They are now building passenger and freight cars 8ft. wide. The superintendent, Mr. W. Borst, says that, were he to begin anew, he would make all the passenger cars 8ft. 3in. wide, outside measurement, giving room, with a narrow isle, for good double seats on each side, as in wide gauge cars. By placing the sills of the narrow-gauge car so much nearer the rail, an angle of safety is secured amply sufficient to prevent overturning, even at high speed; this also greatly diminishes the oscillation of the car, an important point for the comfort of passengers. A Denver editor gives it as his experience that he can write on a narrow-gauge with less difficulty than on any wide-gauge car, not even excepting the Pullman palace.—*Engineering.*

Incrustation in Locomotives.—Mr. F. Kupka, an engineer at Vienna, writes to the German *Organ for Railroad Progress* of some experiments made by Mr. A. Feldbacher, engineer of the Austrian State Railroad Company, on lining locomotive boilers with sheet copper to prevent accumulations of incrustation. Of the three plates forming the bottom of a locomotive boiler, the two at the ends were covered with sheet copper one millimetre (1.25in.) thick, the middle one being left bare. This engine was run two years, making about 14,000 miles in switching service in the Vienna yard, where the water is the worst on the line. On removing the boiler tubes, a layer of incrustation was found 10 millimetres thick on the iron surfaces and two to three millimetres on the copper; the iron exhibited corrosions 1½ millimetre deep; the copper maintained a perfectly smooth surface, while the iron under the copper had the appearance of new plate. The structure of the incrustation was coarser grained on the iron than on the copper. The cost per boiler is given as 50 dols. to 150 dols. Mr. Kupka summarises the advantages of this practice as follows:—(1) The life of the boiler is increased two or three times, and extraordinary security against explosions is obtained. (2) There is considerably less incrustation on the smooth surface of the Copper, than on the porous and somewhat oxidised iron and steel, and therefore a better generation of steam and utilisation of fuel. (3) The boiler plates may

be thinner without danger, in consequence of the favorable action of the copper in preventing corrosion, and consequently the weight of the boiler may be less. (4) The joints of the plates are made perfectly tight by doubling the thin copper sheets over the iron plates and riveting them in. (5) There is a considerable saving in boiler repairs.—*Engineering.*

Railway Accidents in Great Britain.—The Pall Mall Gazette says: The returns relating to railway accidents for the last year has just been issued. From these returns it seems that the total number of persons reported as killed to the Board of Trade in 1875 for the United Kingdom was 2425, and injured, 5050. Of the killed, England contributed 1175; Scotland, 211; and Ireland, 39. Of the injured, the numbers for England are 4468; Scotland, 496; and Ireland, 86. It further appears that there were last year in the United Kingdom, to account for all this killing and wounding, fifty-five collisions between passenger trains or parts of passenger trains; 183 collisions between passenger trains and goods or mineral trains, engines, and vehicles standing foul of the line; 75 collisions between goods trains or parts of goods trains; six collisions between two engines, ninety-seven accidents from passenger trains or parts of passenger trains leaving the rails; seventy-four from goods trains or parts of goods trains, engines, &c., performing the same feat; forty from trains or engines traveling in the wrong direction through points; twenty-one from trains running into stations or sidings at too high a speed; 195 from trains running over cattle or other obstructions on the line; fifty two from trains running through gates at level crossing; six from the bursting of boilers, &c., of engines; eight from the failure of machinery, springs, &c., of engines; from failure of tires, 55; ditto of wheels, 13; of axles, 229; of brake apparatus, 1; of couplings, 23; of ropes used in working inclines, 3; of tunnels, bridges, &c., 4; 493 are charged to broken rails; 10 to blocking of portions of permanent way; 8 to slips in cutting of embankments; 28 to fire in trains; 12 to fire at stations or involving injury to bridges or viaducts; 11 are returned as other accidents. Directors hanged for manslaughter, 0.

ENGINEERING STRUCTURES.

Iron Arched Bridges.—At the last Sessional meeting of the Edinburgh and Leith Engineers' Society, the President, Professor Fleeming Jenkin, read a paper on metal arches. He began by explaining the stresses which occurred in the common masonry arch, illustrating the subject by means of a wooden model of novel description, having each voussoir curved so as to render the arch flexible. It was explained that in papers by Professor Clerk Maxwell, Mr. Bell, and Professor Fuller, of Belfast, methods were given by which the maximum intensity of stress on each part of a metal rib could now be determined with as great accuracy as the stress on the ordinary girders; and Professor Jenkin expressed a strong opinion that the great bridges of the future would be metal arches, which for great spans were essentially more economical than beams, while they also were more beautiful. In illustration, the Bridge of St. Louis, at Cincinnati, was referred to, with a central arch of 520 feet in span. There was no reason why arches of 700 or 800 feet span should not be erected, and in some situations even these great spans would be economical in comparison with a number of smaller openings involving expensive foundations.

The Improvement of the Tiber.—The surveys of the deviation of the Tiber, as proposed by General Garibaldi, have just been completed by the Government engineers, and show clearly the great difficulties in a financial point of view which would have to be encountered in carrying out such a project, whether on the right bank or on the left. The deviation on the left bank—which would be the most favorable—would not cost less than 135 millions of francs, or £5,400,000; whilst that on the right, which would entail a certain length of cutting from seventy to eighty metres in depth, is estimated at 200 millions of francs, or eight mlilions sterling. In our opinion the most feasible scheme so far is that presented some time ago by a well-known engineer, Signor Anderloni, who proposed rectifying the river in its course through the city, giving it a clear waterway of 100 metres, and removing all obstacles—such as the Ponte San'Angelo—which in heavy floods dam back the waters, and cause them to overflow the banks and inundate the city. In the flood of 1870 the water stood at 1.50 above the soffit of the arches of that bridge. Such a work, including a handsome boulevard on each side of the river, with earth embankments for a considerable distance above and below the city, would not probably cost more than fifty millions of francs, or two millions sterling, and would, no doubt, effectually prevent the recurrence of such floods as that of 1870, when, according to Signor Possenti, the President of the Commission for the Tiber, the discharge at Rome reached 2800 cubic metres per second. The removal of the obstacles and the rectification of the river would produce a lowering of the levels of the water in such a flood as that of 1870 of 3.22 metres at Ponte Molle, about 4 kilos. above Rome; of 4.02 metres at Ripetta, where the river enters the city; 1.78 metres at Ripa Grande, where it leaves Rome; and 1.18 metres at the railway bridge, about 1½ kilos. lower still, or 6 kilos. below Ripetta. In this manner the flood level would be reduced at the Ripetta from 17.29 metres above the sea to 13.26 metres, or within the limits of safety. It would be necessary to construct intercepting sewers along the embankment to carry the drainage of the town some distance down the river, and in this manner there would be no danger of those parts of the city which are only 12 metres above the sea being flooded.

Public Works in Jamaica.—From an official document just issued with regard to this subject we glean some information of interest to our readers. One of the most important

works being carried out in Jamaica is the construction of new waterworks for the improvement of the water supply of Kingston. In the carrying out of these works, a dam across the Hope River has been constructed for the purpose of increasing the quantity of water flowing into the culvert. Two reservoirs, at the termination of the culvert near the city, are in course of construction. They will contain 5,000,000 gallons of water. Two filter beds have also been constructed. From the reservoirs the water will flow into the city and its suburbs by a system of iron pipes. The main pipe is 21 inches in diameter. The main and supply pipes have been laid down. Already the works have cost more than $50,000, while it is thought that about $5,000 more will be required for their completion. It has also been decided to build new gasworks for the city of Kingston, and a design was submitted by a London gas engineer, but it was considered too costly. Accordingly it was determined to get a plan of a less expensive character. Another important work in Jamaica is the carrying out of the Rio Cobre irrigation scheme. In reference to this Sir J. P. Grant expressed the hope that it would have been finished long ere now, but he has been disappointed, that is to say, with regard to the head works of the Rio Cobre Canal, the trunk line, and the Caymanas branch. With reference to the progress of the works so far it appears that the foundations of the annicut or dam across the river, the most difficult and expensive portion of the work has been completed, and the dam carried to a height of 10 feet above the foundation in all parts, and in some parts much higher. When finished this structure will be in length 320 feet, reaching all across the river when dammed up; in height it will be 48 feet above the bed of the river, and in breadth or thickness it will be 26 feet at the base and 13 feet at the top. It will contain about 238,000 cubic feet of masonry, besides a mass of concrete. The dam will have suitable sluices and a water cushion. Work on the Trunk Canal and the Caymanas branch has made fair progress. The masonry work on the line consist of three calingulates, or waste water wiers, two aqueducts, one culvert, twenty-three bridges, and eighteen falls.—*Engineer.*

A Notable Railway Bridge.—The railway system of India has necessitated some remarkable engineering works, amongst which may be mentioned the Bhore Ghat incline, from Bombay to Central India. This work, $15\frac{3}{4}$ miles in length, cost, with tunneling, bridges, and embankments, as much as £68,000 per mile, nearly the same as the Semmering Pass in the Noric Alps, joining Vienna and Trieste. The height surmounted in the Ghat incline is 1,831 feet, by gradients averaging 1 in 48, but with 8 miles of 1 in 40, and $1\frac{1}{2}$ miles of 1 in 37. There are also very numerous railway bridges on the Indian lines, as may be inferred from the fact that one English firm alone, Messrs. Westwood & Baillie, of London-yard, Poplar, have already built more than 16,000 iron bridges for the Bombay, Baroda, and Central India and other Indian railways. The firm referred to have just completed and dispatched the last section of the longest bridge they have ever constructed, probably the longest bridge, when its erection has been completed, then in existence. It is to cross the river Chenab in the Punjaub, and will form a part of the through route from Calcutta and Bombay to Lahore, Peshawar, and Cabool. The Chenab is a tributary of the Indus, and has wide low-lying banks, liable to inundation, that are spanned by the bridge. The substructure is to consist of piers of masonry 10 feet 9 inches thick. The superstructure is entirely of iron, and on the Warren girder principle. The total length between the abutments at each end is 9,088 feet, or $1\frac{3}{4}$ miles less 51 yards. The whole work has been built in Messrs. Westwood & Baillie's yard, and has been sent out in sections, every separate part marked, so as to fit into its own place. The last section, of about 100 yards in length, that we saw in the yard was an excellent example of exact work, each end responding perfectly to the test of a wire under high strain applied to it. The bridge will have sixty-four spans, of a clear width of 131 feet 3 inches each. It will carry a single line of the metric gauge, that prevails in India, of 3 feet 3 inches. The width over all is 18 feet, 2 inches, which leaves a sufficiently wide clear space for a footway on each side. The main girders, which are 15 feet 9 inches between centres, are 10 feet 4 inches deep, with flanges of 2 feet 6 inches. The cross box girders, of which there are 1,792 in the structure, are placed at 5 feet $3\frac{5}{8}$ inches apart. The rivets used in the work have been 1,590,592, and have been of $\frac{3}{4}$ inch, $\frac{7}{8}$ inch, and 1 inch rods, according to their situations and the duty required of them. The rods used for these rivets would extend to upwards of 100 miles lineal. The roadway is covered with buckle plates, bent by the firm with their own powerful hydraulic machinery. The weight of the iron used in the bridge is about 6,000 tons. If all the pieces of iron employed in the structure, girder plates, struts, ties, buckle plates, etc., exclusive of the rivets, and irrespective of the width of the pieces, were laid end to end, they would extend to a length of 250 miles. The whole of the work for the riveting has been drilled, not a single rivet-hole having been punched. We have heard that the Government, or official authorities in the Punjaub concerned with the erection of the bridge, have expressed their satisfaction with the materials and workmanship. The whole was completed in London-yard in eighty-six weeks. —*Engineering.*

ORDNANCE AND NAVAL.

The "Bessemer."—Those of our readers who have read the accounts of the trial trip given in the daily papers, will probably be disposed to thus summarize what they have read :— The swinging saloon does not yet swing, the "Bessemer" does draw more than eight feet of water, her speed is very much less than twenty miles an hour even in fine

weather, and she is not adapted for the present French harbors because of her great length, and consequent liability to be swung round by the tide. So much, apparently, has performance fallen below promise, that some of our contemporaries have gone so far as to say that the "Bessemer," whatever else she may be adapted for, cannot be used successfully as a passenger boat between, Dover and Calais until there is a larger and better harbor made on the French side. We are, at present, far from any such conclusion as this, and so we think will our readers be after hearing what can fairly be said on the other side of the question.—*Nautical Gazette.*

STEAMERS FOR HAYTI.—Messrs. Nefie & Levy, of Philadelphia, have on hand two war steamers for the Haytian Government. The steamers are being built of wood, and the contract for their hulls have been sub-let to Messrs. Birely, Hillman & Streaker. The larger of these two vessels will be of 700 tons burthen, and she will be 190 feet long by 32 feet beam, and 14 feet depth of hold. The vessel will be fitted with direct-acting horizontal engines of the surface condensing type, with cylinders 38 inches in diameter and 24 inches stroke. Both engines and boilers are to be completely surrounded by coal bunkers, as a protection against shot and shell from an enemy. The steamer's armament will consist of an 11-inch Rodman gun amidships, two 30-pounder Parrott rifles at either end, and two broadside 32-pounder smooth bores. The smaller vessel will be 158 feet long by 29 feet beam and 12 feet depth of hold. Her engines will be of the same type as those of the other steamer; the cylinders will be 32 inches in diameter by 20 inches stroke.—*Engineering.*

THE *Borsenzeitung* says that it is to be decided in the course of the present summer whether the two gunboats built for service on the Rhine are to form the nucleus of a gunboat flotilla to be permanently established on that river. The gunboats in question, together with the two French ones which were captured in the second battle of Orleans, will make various trial trips on the river for the purpose of ascertaining whether the establishment of such a flotilla would be desirable. It is not proposed to use these boats for any other object than to strengthen the defences on the Rhine, and if the creation of a flotilla should be determined upon it will be divided into squadrons to be attached to the various fortresses. The reason of this is that the difficult navigation of the Upper Rhine and the strong currents in that part of the river would make it almost impossible to send the boats up the stream. On the Lower Rhine, however, between Cologne and Coblenz, a single squadron will be sufficient to provide for the defence of the whole of that section of the river. The French gunboats are covered with plates from five to eight centimetres thick, and have engines of forty horse power. They draw from 1.1 to 1.25 metres of water, carry a sixteen or twenty-four centimetre gun and a light field gun or mitrailleur, and have crews of from twenty-six to forty-five men. The armament of the new German gunboats is not yet decided on.—*Engineer.*

WE noticed some time ago, says the *Pall Mall Gazette*, the force and originality of the views which Admiral Porter took occasion to impress upon his countrymen in the annual report on the United States' Navy. Those of his suggestions which referred to the construction of a single small but efficient ironclad squadron, backed by a few swift corvette cruisers, to supersede the present antiquated and almost useless vessels on the list, remain still in abeyance. But the late votes of Congress have been applied partly to another, the improvement of the offensive torpedo service. Admiral Porter avowed his belief that torpedoes used merely passively would greatly disappoint their designers; and he even satirised the late experiments made by projecting them from the bows of slow, worn-out steamers. But he expects great things from a bold use of these weapons offensively by properly constructed vessels, and the new torpedo steamer, the Alarm, lately launched at Brooklyn, is the first attempt to give practical effect to his views. As in the case of the Dantzic torpedo boats of Germany, speed is a special object, and the lines are consequently fine and the engines powerful. But the Alarm is over 300 tons measurement, thus many times larger than the similar models of the Baltic builder, and is to carry one very heavy gun as a reserve, in case her torpedo boom falls, with Gatling guns for her own protection from boat attacks. As she is built with a wheelhouse, this, as well as her size, will prevent her having the comparative invisibility on which the German inventors much rely for the efficiency of their squadron. But, on the other hand, the Alarm is constructed to face a sea in which their low and fragile vessels would be quite useless.—*Engineer.*

LIGHTHOUSES AND WRECK-SIGNALS.—Owing to the wreck of the "Schiller," and to the absence of any means of making it known to the shore by the men in charge of the Bishop Rock Lighthouse, many suggestions have been made, amongst others, that a telegraphic wire should be laid between the Bishop Rock Lighthouse and the land, and that a similar arrangement should be made in the case of all other detached lighthouses. It appears to us that there are four objections to this. The first is, that vessels would be more frequently tempted to approach the lighthouses for the purpose of reporting themselves, and thus actually run into proximity to danger. The second is, that a telegraphic cable would, in such a position among rocks and breakers, be speedily liable to damage and even destruction, and would, at the best, be untrustworthy; the third is, that the occasions when such a wire might be useful would be so extremely rare (for it certainly must not be used for any other purpose than as a distress signal) that from disuse the keepers would have difficulty in remembering how to work it, and the apparatus would be very liable to get out of order; and the fourth is, that a telegraph wire is really unnecessary for the purpose. The Marine

Department of the Board of Trade have had manufactured for them by the War Department a new sort of rocket, which the department has named a "call" rocket. It is to be used only when a ship is seen to be in distress, wanting assistance from the shore. At present the "call" rocket has been supplied to light ships only, but we would throw it out as a suggestion whether it should not be also supplied to outlying lighthouses like the Bishop Rock. It is a day signal as well as a night signal, and is quite distinctive. No one can possibly mistake it for any other rocket or signal. It reaches an altitude of 2,500 feet, carries up with it a very large charge of powder, which explodes with a great noise, and also shows both in its upward and downward course a very powerful magnesium light.—*Nautical Magazine.*

BOOK NOTICES.

THE YEAR BOOK OF FACTS IN SCIENCE AND ARTS FOR 1874. Edited by C. W. VINCENT, F. C. S., etc. London: Ward, Lock, & Tyler. For sale by Van Nostrand. Price, $1.25.

THIS is a fresh issue in a new cover of a very old and well-known annual. Mr. Timbs, its originator, has unfortunately departed, but his mantle has descended upon Mr. Vincent, who has rehabilitated and thrown fresh vigor and force into a very valuable book. There were indications in the recent volume that Mr. Timbs' sources of information were narrow and few, but Mr. Vincent has gone wider and further afield, and the value of the book is enhanced accordingly. It is a very useful work of reference.—*Telegraphic Journal.*

HAND BOOK OF LAND AND MARINE ENGINES. By STEPHEN ROPER, Engineer. Philadelphia: Claxton, Remsen & Haffelfinger. Price, $3.50.

This work includes the moulding, construction, running and management of engines and boilers. It is a compendium in convenient form of the miscellaneous information required by the engine builder or engine driver.

Besides descriptions of many of the leading forms of engines, there are minute directions for the adjustments of those parts which the young engineer needs most to learn at once. There is no attempt to be philosophical on the part of the author, but the information given is straightforward and plain talk rather brief.

PRACTICAL HINTS ON THE SELECTION AND USE OF THE MICROSCOPE. By JOHN PHIN, Editor of the Technologist. New York: Industrial Publishing Co. For sale by Van Nostrand. Price, 75 cts.

The use of the Microscope is rapidly extending. Whether used for popular amusement or popular instruction its value is beyond all computation superior to that of the telescope. Every school should have a compound microscope, and every pupil old enough to feel interested in natural science should learn to use one.

How to select an instrument, and how to collect and observe objects is exceedingly well told in this little book. We recommed it to all who have not access to the larger manuals.

THE YOUNG SEAMAN'S MANUAL, COMPILED FROM VARIOUS AUTHORITIES FOR THE USE OF THE U. S. TRAINING SHIPS AND THE MARINE SCHOOLS. New York: D. Van Nostrand. Price, $3.00

The title of this book explains its scope. The minuteness of the information can be judged from the topics treated in separate chapters; they are as follows, viz: I. The Compass and Lead; II. Knotting and Splicing; III. The Log; IV. Rope; V. Blocks; VI. Tackles; VII. The Mast—The Rudder; VIII. Cutting and Fitting Rigging; IX. Masting; X. Rigging Ship; XI. Sails; XII. Boats.

The book is eminently fitted for the purposes of instruction. The typography is excellent, with all technical terms printed in heavier type than the context, and the whole illustrated by 350 good cuts.

THE ENGINEERS, ARCHITECTS, AND CONTRACTORS' POCKET-BOOK FOR THE YEAR 1875. London: Lockwood & Co. For sale by Van Nostrand.

THIS has been long known as "Neale's Engineers' Pocket-Book," and has been jointly prized for the extent and accuracy of its information.

A new edition appears yearly, but the changes in the more valuable portions of the volume are few or none. The calender and lists of officers of scientific societies, of course, are changed for each new year.

A yearly pocket-book of formulas is presumably freer from typographical errors than other similar works in that portion of the book which is reprinted year by year, as each new edition is a new opportunity for correction. Such, we believe, to be the merit of this pocket-book.

PRIME COST KEEPING, FOR ENGINEERS, IRONFOUNDERS, BOILER AND BRIDGE MAKERS, &C., PRACTICALLY EXPLAINED, WITH THE METHOD OF ARRIVING AT ALL THE GENERAL AVERAGES REQUIRED. By JOHN WALKER. Liverpool: Dunsford & Son.

Nothing is more essential to the prosperity of an engineering establishment than the employment of an efficient system of keeping the prime cost accounts, and this being so we are glad to notice the publication of the useful manual now before us. Mr. Walker appears thoroughly familiar with his subject, and he treats it in full detail, giving sample pages of the books suitable for keeping the accounts of the different departments of an engineering works, and explaining the mode of preparing general averages and getting out the total costs of articles involving different classes of work. Altogether the book is calculated to be very useful to those who have not an efficient system of prime cost keeping in operation at their establishments.—*Engineering.*

HINTS TO YOUNG ARCHITECTS. By GEORGE WIGHWICK, Architect. A New Edition, revised and considerably enlarged, by G. HUSKISSON GUILLAUME, Architect. London: Lockwood & Co. For sale by Van Nostrand. Price, $1.40.

An examination of this book shows that it forms a material extension of the work upon which it is founded. Thus Parts IV., V., and VI., comprising about a hundred pages, are entirely new, while other parts of the book have received many additions and revisions. The three first parts of the work refer respecttively to the school studies, studies abroad, and early practice of a young architect, and contain numerous hints and suggestions of value. Then come the three new parts already mentioned—these dealing with the principles of construction, sanitary construction, and design—and lastly, we have a model specification, which appears to have been well revised in accordance with modern practice. The book is one well calculated to be of service to the class for whom it has been written.—*Engineering*.

EUROPEAN LIGHT HOUSE SYSTEMS. By MAJ. GEO. H. ELLIOT. New York: D. Van Nostrand. Price, $5.00.

This report is the result of observations made during a tour of inspection in 1873 under the direction of the Light House Board. The writer seems to have been exceedingly well qualified both for the inspection and for the report of it, and the result is a work interesting to an exceptional degree.

Fifty-one engravings and thirty-one wood cuts illustrate the work; all are well executed.

In summarizing his preliminary report which forms a preface to the complete work, the author says: "While the British and French systems are necessarily very much like our own, I saw many details of construction and administration which we can adopt to advantage, while there are many in which we excel. Our shore fog-signals, particularly, are vastly superior both in number and power. They are in advance of us in using both the gas and electric lights in positions of special importance; in the use of horizontal condensing prisms for certain localities; in the character of their lamps; in the use of fog-signals in light-ships; in their light-ships with revolving lights, and more than all, in their character of their keepers, who are in service during good behavior until death or superannuation, who are promoted for merit, and whose lives are insured by the government for the benefit of their families."

The report has already been widely commended.

HYDROLOGY OF SOUTH AFRICA; OR, DETAILS OF THE FORMER HYDROGRAPHIC CONDITION OF THE CAPE OF GOOD HOPE AND OF CAUSES OF ITS PRESENT ARIDITY. By JOHN CROUMBIE BROWN, LL.D. Kirkaldy: John Crawford.

THIS work offers testimony bearing on a question of great interest, viz.—possible changes in the moisture of the climate of a section of country and the probable causes of the change.

The work is divided into three distinct parts, which are not divided in chapters and sections. The "parts" treat respectively of—

I. Former Hydrographic Condition of South Africa.

II. Cause or Occasion of the Desiccation of South Africa.

III. Aridity and Water Supply of South Africa.

In conclusion the author holds that corresponding accounts might be given of the hydrology of other lands, and that appropriate remedies are the erection of dams to prevent the escape of a portion of the rainfall to the sea; the restriction of the burning of the *veldt;* the consummation and extension of existing forests; and the adoption of measures similar to the *reboisement* and *gazonnement* carried out in France with a view to prevent the formation of torrents, and the destruction of property occasioned by them.

A large portion of the work is compiled from standard writers on physical geography.

A TREATISE ON RAILWAY SIGNALS AND ACCIDENTS. By ARCHIBALD D. DAWNAY, Assoc. Inst. C. E. London: E. & F. N. Spon. Price, 80 cts. For sale by Van Nostrand.

MR. DAWNAY has chosen for this treatise a subject on which little has been written, while that little is to be found chiefly in the Transactions of scientific societies which are not accessible to the general public. The popular description of railway signaling to be found in the volume before us is, therefore, likely to be appreciated. Commencing with an account of the earlier forms of signals or semaphores used for communicating intelligence, Mr. Dawnay proceeds to describes the numerous varieties of signals now in use on the railways of this country, his explanations being illustrated by numerous engravings. The second part of the work is similarly devoted to descriptions of the various forms of locking gear and systems of electric signaling, while in the third the author treats of railway accidents due to defective signaling, his record being a very interesting one.

The fourth part of Mr. Dawnay's treatise deals with the defects of signaling arrangements as frequently carried out, and contains suggestions for improvements. These latter are of a practical kind, and have apparently been well considered. The author is evidently well acquainted with his subject, and he enters into its details carefully, and without showing any prejudice in favor of particular schemes. With his remarks on the habitually loose working of the block system on many lines we thoroughly agree, and we have on numerous occasions condemned the policywhich renders such working possible and even necessary. Altogether Mr. Dawnay has produced a very interesting and useful treatise, which we have pleasure in recommending to all interested in railway signaling.—*Engineering*.

A PRACTICAL TREATISE ON THE SCIENCE OF STEAM. By N. P. BURGH. Part I. London: N. P. Burgh. For sale by Van Nostrand.

Mr. Burgh is adding another to the long list of his "practical treatises." We have now before us the first part, containing two excellent plates—the best feature all our author's works—and eight pages of letterpress. We regret that Mr. Burgh does not pay a little more attention to correct modes of expression,

exactness of language being absolutely essential in scientific literature. Old and hackneyed theories, however, are wholly discarded, and even Galileo and Tyndall are left behind by our author, who explains latent heat thus:—"Electricity is at the bottom of it all, but to what extent and how that property is upheld and mantained by the Great Creator is beyond our wisdom." The wonderful effects of heat are thus described :—"Heat also is a most powerful agent, as for example, it will reduce solids to ashes, and also form liquids, and cause the latter to evaporate as a vapor with a small sediment behind. In fact, heat is the reverse of cold, while both are governed by the same law." Perhaps the most remarkable statement in the part is an explanation of the generation of steam in iron boilers. In some cases, it appears "*the flame passes through the plate* in a filtered form, and forms steam with the water." The explanation of this fact—which our author does well to express in italics —is, that "there is a space filled with vaporised water between the top surface of the plate and the bottom of the water. The flame then ignites this vaporised water, and it becoming lighter than the volume above, ascends and heats the surrounding currents it passes through." Mr. Burgh has only to fully corroborate this to establish his claim to be considered one of the most remarkable discoverers of our century !—*Iron.*

MISCELLANEOUS.

CASTING METALS.—Messrs. Farnsworth & Sanson, of Mansfield, has patented some improvements in apparatus used in forming moulds for the casting of metals. According to the invention, the moulding table is formed with a true surface, and is fitted to receive the moulding boxes and the mould plate. The moulding boxes used are fitted with pins on one half and holes in the other, and are all in duplicate. The patterns are secured to a pattern plate, and are capable of sliding through the mould plate, the forms of the one being exactly the counterpart of the other, so that the sand is prevented from being pulled down in the withdrawal of the pattern. The pattern plate is capable of being slid up and down in the framing, and is operated for this purpose by a pinion acting on a rack to the table, such pinion being actuated by ordinary gear and hand wheel or other means.

HAND PUMPS.—Mr. J. Davison, of South Shields, engineer, has patented an invention which relates to the removal of dead centres in crank shafts, and is effected by keying on to a straight longitudinal shaft, supported in journals, a hollow barrel with solid ends. This barrel is divided diagonally and spirally into two portions, and so set apart from each other as to permit a pin to travel to and fro on the shaft and between and along the divided edges of the two portions. Connected to the external end of the pin is an upright arm fixed to the cross-head that works on a centre below the barrel. When the pin is driven to and fro along the shaft by the revolution of the barrel, the pin carries with it the upright arm of the cross-head, causing the sum to oscillate, and by that means giving motion to the pump rods attached to the two horizontal arms of the cross-head.

THE *Revue d'Artillerie*, published by order of the Minister of War in France, contains the report of Major Bobillier, of the artillery, on the experiments made last year at Creusot in steel, for the construction of cannon. The object of M. Schneider was, of course, to produce a metal that should be free from the faults of both cast iron and bronze, and, according to the report, this object has been obtained; for, in the words of a communication made by General Morin to the Paris Academy of Sciences, on the last day of August—"On the one hand accidents like those which caused the Russian Government to reject a whole material of artillery from the famous establishment of Essen are not to be feared with the soft steel tried at Creusot; and, on the other, the three pieces of 78 m. 6 m.—310 in.—experimented on, supported without reaching the limit of their power of resistance, and without being deformed, nearly as much as bronze would have done under the same circumstances, the most severe trials, and to which guns of the calibre are never submitted in ordinary service." The experiments are still being pursued, but General Morin told the Academy that it might be safely asserted that the establishment at Creusot possessed the necessary elements for the production of cannon in steel, with all the qualities demanded for artillery, namely, resistance against fracture and deformation.

TWO very curious articles have been published by a Shanghai native newspaper, the *Hwei-Pao*, protesting against the construction of railroads in the Chinese Empire. The *Hwei-Pao* is of opinion that the existence of railroads in Europe is too recent to admit of a judgment being formed as to their practical utility, and, moreover, that there is not sufficient business in China to render them profitable. The Chinese journal goes on to say that "tea and silk are the principal objects of commerce, and these have hitherto been forwarded to the treaty ports by river steamboats. A substitution of railroads for steamboats would not effect any saving in point of time, and could not, therefore, even from the point of view taken by the foreigners themselves, be of any service to China. Admitting that a little time was gained, the Chinese would not be benefitted, for the goods would not be exported more rapidly. Thus the railroads would only lead to an accumulation in the ports of vast quantities of goods which, as they would not be shipped off all at once, would fall considerably in price." The *Hwei-Pao* also says : "The accidents on the railroad lines are very numerous, caused by collisions, by the engines or tenders taking fire, by the trains running off the lines, or by bridges giving way and the trains being precipitated into the rivers below. In other cases the carriages are injured by the great speed at which they are car-

ried along, and the accidents are so numerous that it is often impossible to ascertain the exact number of dead and wounded. All the foreign journals are full of details concerning these accidents. But admitting that most of these casualties are preventible, and that the trains follow their regular course, they travel quicker than the thoroughbred horse, and the people walking on the lines would have no time to get off their way. From this cause alone the number of fatal accidents would be enormous. In all countries where railroads exist they are considered a very dangerous mode of locomotion, and beyond those who have very urgent business to transact, no one thinks of using them."

The Horse-Power of the World.—Dr. Engel, director of the Prussian Statistical Bureau, has been making estimates on such statistical data as are available of the total horse-power of steam engines in the world, as every country has tolerably correct railroad statistics. Dr. Engel thinks that the following returns with reference to locomotives are not far from right:

	Year.	Number.
United States	1873	14,223
Great Britain	1872	10,933
Zolverein	1871	5,927
Russia	1873	2,684
Austria	1873	2,369
Hungary	1869	506
France	1869	4,933
East Indies	1872	1,323
Italy	1872	1,172
Holland	1872	331
Belgium	1870	371
Switzerland	1868	225
Egypt	1870	212
Sweden	1872	185
Denmark	1865	39
Norway	1871	34
Total		45,467

It may be assumed that there are still four or five thousand additional locomotives in countries from which no statistics have been received, so that something like fifty thousand engines of that description, of an aggregate of 10,000,000-horse power, all now in use. Dr. Engel estimates all the engines in use, locomotive, marine and stationary, at about 14,400,000-horse power.

Rotary Puddling Furnaces.–Messrs. Jones, of Middlesborough, have patented some improvements in rotary puddling furnaces. The invention consists—1. In admitting water intermittently to the space between the casings of the furnace (when the furnace is composed of 2 casings) by various modes or contrivances, one mode being by means of valves or cocks; another method is by means of scoops or bent pipes, or in some cases by a coil of pipes or annular space or duct formed round outside of the revolving furnace; and another plan by means of buckets arranged at intervals around and attached to the outside of the outer casing.—2. In effecting the egress of the water from the water space of the rotary furnace by means of pipes, channels, or ducts, one or more of which are coiled round the outside of the outer casing, and communicate at one end with the water space.—3. In forming the rings which are secured round the ends of the furnace (and which are divided into two or more segments) with recesses on their outer faces respectively, which recesses fit over corresponding projections on the outer faces of the rings against which the furnace rings revolve, and serve to maintain a tight joint and to prevent the waste of cinder and iron thereat; also in connecting the water-pipes (which are cast in the bodies of the rings) at their external ends outside the furnace with the water space between the casings by means of branch pipes or connecting pipes.—4. In constructing the cast iron or steel end of a single-cased rotary furnace in two or more pieces or segments which are respectively attached to the circular flanged end of the furnace by bolts, and to each other by internal or external flanges and bolts.

Dimensions of the Earth.—Two German scientific men, Messrs. Behum and Wagner, have recently published the results of some very accurate measurements that they have made respecting the dimensions of the earth. From these it appears that the length of the polar axis is 12,712,136 metres, that of the minimum equatorial diameter, which is situated 103 deg. 14 min. east of the meridian of Paris, or 76 deg. 46 min. west, is 12,752,701 metres, whilst the maximum diameter at 13 deg. 14 min. east, and 166 deg. 46 min. west, is 12,756,588 metres. They estimate the total surface of the globe at 509,940,000 square kilometres, whilst its volume is equal to 1,082,860,000,000 cubic kilometres. The circumference of the globe on its shortest meridian is 40,000,098 metres, whilst that of the longest is 40,069,903 metres. The oceans and glaciers occupy 375,127,950 square kilometres. The total number of inhabitants of the earth is estimated at 1,391,000,000—viz., 300,530,000 in Europe, 798,000,000 in Asia, 203,300,009 in Africa, whilst the population of America is 84,542,000 and that of Oceana 4,438,000. The population of the towns and cities exceeding 50,000 inhabitants is 69,378,500, or about one-twentieth part of the total population of the globe, leaving nineteen-twentieths of the inhabitants for the villages and smaller towns.

The change of proprietorship of the *Evening Star* and the issue of the paper from the office of the *Glasgow News* were announced by 1,025,000 little hand-bills, which were printed in the incredibly small space of half an hour. Such a feat of rapid printing, we believe, has never before been performed, and it would have been impossible to perform it but for the Walter Press. The process was interesting. The small hand bill, measuring three inches by two, was reproduced by stereotyping to the extent of 336 times, and by 4,000 revolutions of the Walter Press the million bills were printed. It occupied ten hours to cut them up with a steam guillotine machine, and they were distributed throughout the town from the windows of two carriages.

VAN NOSTRAND'S

ECLECTIC

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ELEMENTARY DISCUSSION OF STRENGTH OF BEAMS UNDER TRANSVERSE LOADS.

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Written for Van Nostrand's Engineering Magazine.

II.

Case IV.

Let the load be equally distributed over the beam (Fig. 32). In this case the reaction of each abutment $=\frac{1}{2}$ the load, or

$$R_1=\frac{wl}{2}=R_2 \qquad (36)$$

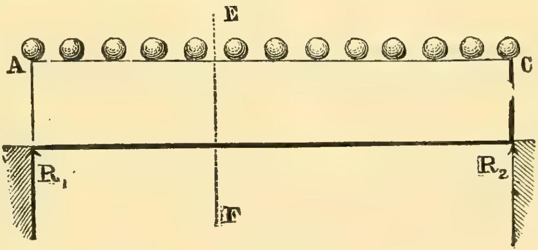

Fig. 32.

Take any section E F whose distance from $A=x$. Then the external forces acting between A and E F are, R_1 and the resultant of all the little weights from A to E $(=wx)$. This last force acts at its centre of gravity (Fig. 33),

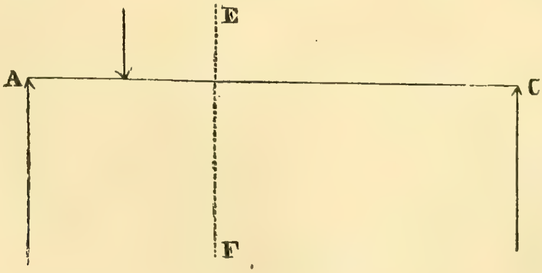

Fig. 33.

Which is half way from A to E. Its lever arm is therefore $=\frac{x}{2}$. Hence the equation of moments will be

$$\left.\begin{array}{ll} & \frac{w\,l}{2}.\,x-\frac{w\,x^2}{2}=\frac{1}{6}\,\mathrm{S}\,b\,d^2=\mathrm{M} \\ \text{or} & \frac{w\,x}{2}\,(l-x)\;=\frac{1}{6}\,\mathrm{S}\,b\,d^2=\mathrm{M}\end{array}\right\}\quad(37)$$

This is a maximum at the centre where

$$\mathrm{M}_0=\tfrac{1}{8}\,w\,l^2\qquad(38)$$

The shearing force at E F is

$$\mathrm{T}=\frac{w\,l}{2}-w\,x\qquad(39)$$

This is greatest at the abutments where $x=l$, or 0

$$\therefore\ \mathrm{T}_0=\frac{w\,l}{2}\qquad(40)$$

At the centre $\quad\mathrm{T}=0$

Geometrically. The values of M in eq. (37) may be represented by a para-

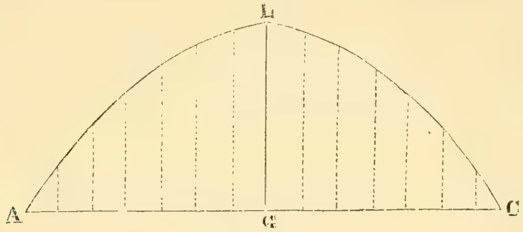

FIG. 34.

bola with vertex at L, the ordinates G L (Fig. 34) being taken $=\mathrm{M}_0$. The shearing force is represented by the two triangles A P G and G Q C (Fig. 35).

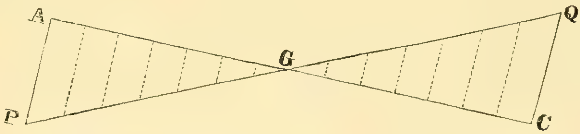

FIG. 35.

The maximum moment exists at the point (G) when the shearing force is zero.

Corollary. When the uniform load extends only over a certain distance from one of the supports, as in (Fig. 36),

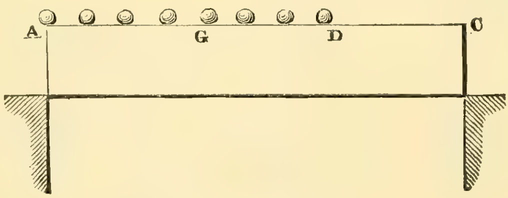

FIG. 36.

let A D=loaded segment$=m$. The reactions of the abutments are:

$$\left.\begin{array}{l}\text{At A, } \mathrm{R}_1=w\,m\left(\frac{l-\frac{1}{2}m}{l}\right) \\ \text{At C, } \mathrm{R}_2=w\,m\left(\frac{m}{2\,l}\right)\end{array}\right\}\quad(41)$$

Then for any section in A D the moments of the external forces will be as in the case just discussed,

$$=w\,m\left(\frac{l-\frac{1}{2}\,m}{l}\right)x-\frac{w\,x^2}{2}$$

And the equation of moments in A D will be:

$$w\,m\left(\frac{l-\frac{1}{2}\,m}{l}\right)x-\frac{w\,x^2}{2}=\frac{1}{6}\,\mathrm{S}\,b\,d^2=\mathrm{M}\quad(42)$$

For any section in D C the whole load $(w\,m)$ is to be considered as acting

through its centre of gravity (G), and the equation of moments is:

$$wm\left(\frac{l-\frac{1}{2}m}{l}\right)x-wm(x-\tfrac{1}{2}m)=\frac{1}{6}Sbd^2=M$$

Reducing

$$\frac{w\,m^2}{2\,l}\,(l-x)=\frac{1}{6}\,S\,b\,d^2=M \qquad (43)$$

The shearing force in A D is

$$\left.\begin{aligned}T&=w\,m.\left(\frac{l-\frac{1}{2}m}{l}\right)-w\,x\\ \text{In D C, } T&=w\,m.\left(\frac{l-\frac{1}{2}m}{l}\right)-wm\end{aligned}\right\} \qquad (44)$$

T is a maximum at A, or

$$T_0=w\,m\left(\frac{l-\frac{1}{2}m}{l}\right)$$

Geometrically. Eq. (42) corresponds to the parabola A L K (Fig. 37), which

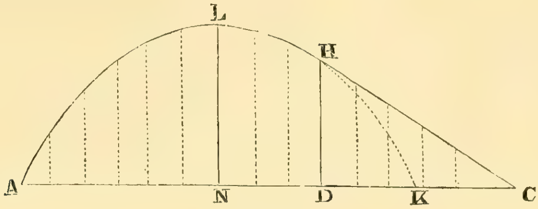

FIG. 37.

cuts A C at A and K (whose distance from $A=\frac{2\,m}{l}\,(l-\frac{1}{2}m)$) and whose axis is vertical. Eq. (43) corresponds to the straight line H C. We only use the part A L H of the parabola, the moments in D C being represented by the triangle D H C. The maximum moment is at N corresponding to the vertex L of the parabola. The value of this moment is:

$$M_0=\frac{w\,m^2}{2}\left(\frac{l-\frac{1}{2}m}{l}\right)^2 \qquad (45)$$

which is obtained from eq. (42) by substituting for x the value A N $(=\frac{1}{2}$ A K$)=\frac{m}{l}(l-\frac{1}{2}\,m)$. This M_0 is always less than the maximum moment that exists when the load extends all over the beam as will appear by making m to vary in eq. (45) and applying the tests for a maximum to it.

The shearing stress for the loaded segment is represented by the triangles A P K and K P′ D (Fig. 38), and for the

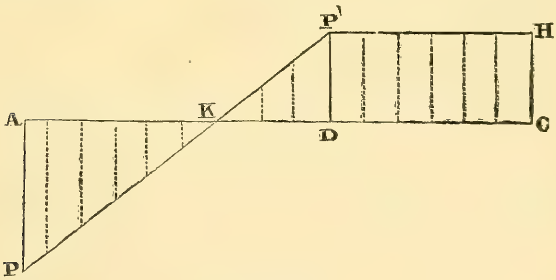

FIG. 38.

other segment by the rectangle D H. The point K, where the stress is zero, is found by making in eq. (44)

$$T=w\,m\left(\frac{l-\frac{1}{2}\,m}{l}\right)-w\,x=0$$

and finding the value of x.

This point corresponds to the maximum moment. It may also be found graphically by constructing Fig. 38, and, as before, affords the easiest method of determining the point of the beam where the maximum moment exists and where consequently there is greatest danger of rupture.

EXAMPLES.

1. Let $l=20$ ft. $w=500$ lbs. per ft. $m=15$ ft. and let there be a weight in

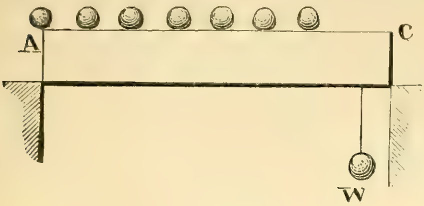

Fig. 39.

addition. W=5 tons at a point 18 ft. distant from A. Required the maximum moment.

2. Let one-half of the above beam be loaded with a uniform load, $w=1$ ton

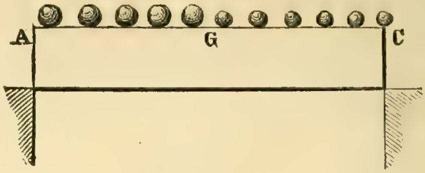

Fig. 40.

per foot, and the other half with a uniform load of $w'=\frac{1}{2}$ ton per foot. Required the moments.

Case V.

A single moving load. When a single moving load passes over a beam, as in (Fig. 41), the maximum moment at each

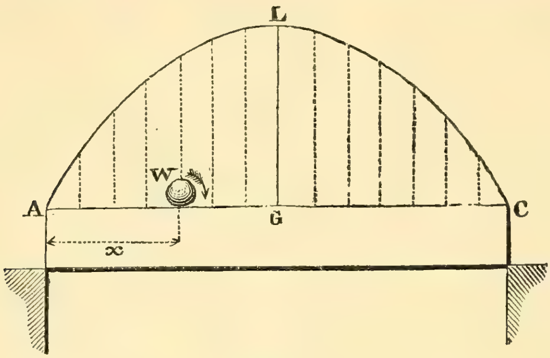

Fig. 41.

instant (as appears from *Case III.*) takes effect at the section just under the weight. To determine the law of variation of these maxima as the weight travels over the beam: Let x=the distance at any instant from A, and then the reaction of A at that instant (=the part of W transmitted to it)$=W\dfrac{l-x}{l}$ Multiplying this by the lever arm x we have for the moment under the weight:

$$\frac{Wx}{l}(l-x)=\frac{1}{6}Sbd^2=M \qquad (46)$$

This is a maximum at the centre, where

$$M_0=\tfrac{1}{4}Wl \qquad (47)$$

Eq. (46) corresponds to a parabola (Fig. 41) with vertex at L, the ordinate GL being$=\frac{1}{4}Wl$. The shearing force for each segment into which W (Fig. 42) at any instant divides the beam is equal to the reaction of the abutment corresponding to that segment. Thus, if W is at a distance x from A the reaction of A is$=W\dfrac{l-x}{l}$ and of C it is$=W\dfrac{x}{l}$.

If W has the position marked 2 in (Fig. 42), then the shearing stress in the left segment is shown by the rectangle $ANN'W$ and in the right segment by the rectangle $WN''N'''C$. The diagram shows in a similar way the stress at other points. If the third position of W in the figure is at the centre of the beam then evidently the greatest shearing stress to be provided for in the left half of the beam will be represented by the *locus* of the points like L, N′, P′, and for the right half it will be the *locus* of the points P″, Q″, L′, etc.

These *loci* are given by the equations:

$$\left.\begin{aligned} T&=\frac{W}{l}(l-x)=\text{eq. of } LC \\ T&=\frac{W}{l}x \qquad =\text{eq. of } AL' \end{aligned}\right\} \quad (48)$$

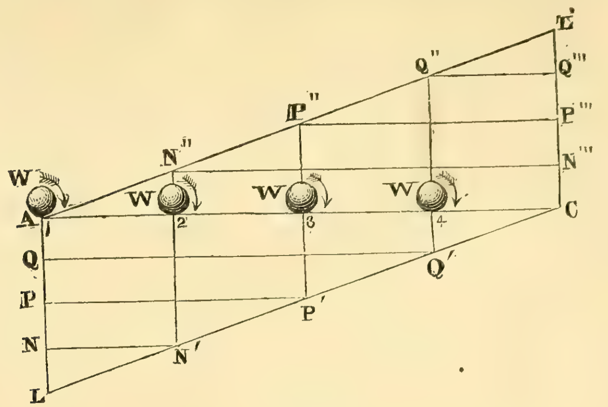

FIG. 42.

Turn the triangle A L′ C down for convenience, as in (Fig. 43), and then the shearing stress to be provided for is given by the figure A L P L′ C. In this figure A L = C L′ = W and D P = $\frac{W}{2}$.

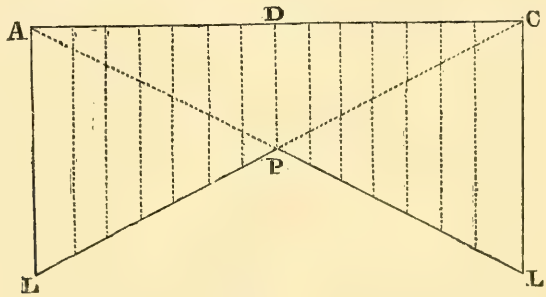

FIG. 43.

Case VI.

A distributed moving load. When a moving load gradually covers a beam, (Fig. 44), moving on from one end as a long train of cars, the maximum moments produced is that due to the load

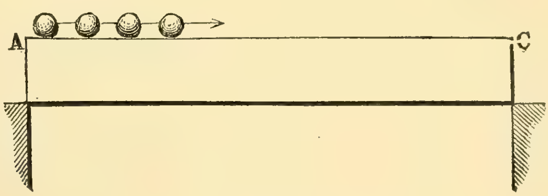

FIG. 44.

when it covers the entire length of the beam, and consequently this case is provided for in *Case IV.*

But with the shearing stress it is different. Here, as in *Case V.*, we need the *locus* of the greatest shearing stresses that can be brought upon the beam. This maximum at any section D occurs when the longer segment into which D divides the beam is loaded, and the other is not. In that case the shearing force at D (= the reaction of the abutment C) is

$$T = \frac{w\,x^2}{2\,l} \qquad (49)$$

This equation gives the parabola A N P′ (Fig. 45) with vertex at A, where C P′ = $\frac{w\,l}{2}$. When the load comes from

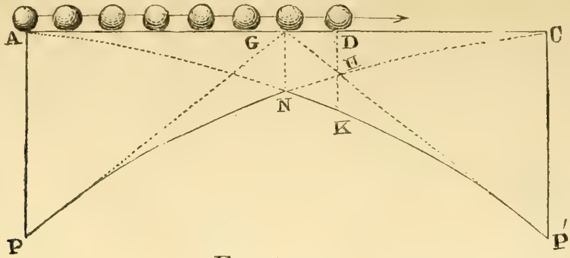

FIG. 45.

the other end of the beam we get the parabola C N P. Hence the figure A P N P′ C gives the maximum shearing stress to be provided for.

It is easy to see that the shearing stresses thus obtained are greater than those which exist when the load covers the entire beam. In the latter case the forces are represented by the triangles A P G and G P′ C (Fig. 45), the shearing stress at D being given by eq. (39)

$$T = wx - \frac{wl}{2} = DH$$

In the case of the passing load we have just seen that

$$T = \frac{wx^2}{2l} = DK$$

The value of D H is always less than that of D K when $x \geq \frac{l}{2}$; for if $2x$ be a certain quantity, then the product of the halves of that quantity ($=x^2$) is greater than the product of any other two parts (such as l and $[2x-l]$) into which it can be separated.

$$\left.\begin{array}{ll} \text{That is} & x^2 > l\,(2x-l) \\ \therefore & \dfrac{wx^2}{2l} > \dfrac{wl\,(2x-l)}{2l} \\ \text{or} & \dfrac{wx^2}{2l} > wx - \dfrac{wl}{2} \end{array}\right\} \qquad (50)$$

In the expressions for the moment of resistance $M = \frac{1}{6} S b d^2$ the quantity denoted by S (= the stress on the outside fibres) varies directly as M. Hence, all the geometrical illustrations we have given of the *moments* may apply equally well to the values of S. The maximum moments give the maximum stress on the fibres, and indicate the points of rupture when the beam is loaded with its breaking weight.

ULTIMATE VALUES OF S.

If beams are loaded transversely until fracture takes place, the value of S or the stress on the outside fibre which exists at the moment of fracture, gives us a value for the tensile or compressive strength of the material according to the manner of rupture. If the beam yields by *tearing*, S gives us the tensile strength, if by *crushing* S gives the compressive strength. We readily obtain the value of S answering to the ultimate strength from any of the formulas under "Transverse Stress," by substituting given values for l, b, and d and the actual breaking weight for W.

But the tensile and compressive strengths of materials are also obtained by direct tension and compression, the force being applied in the direction of the length of the bars until rupture takes place.

If our theory were perfect the values of tensile and compressive strength thus deduced would agree with the ultimate values of S found in transverse stress; but they do not.

The difference is very wide sometimes. Thus in cast-iron, S (in this case it represents the tensile strength) derived from breaking rectangular beams by a transverse load is nearly 20 tons per square inch, while the tensile strength obtained directly is only about 8 tons. This discrepancy has been accounted for in two ways.

1. That the neutral axis moves towards the compressed side, and that therefore a larger portion of the beam is subjected to tension than the formula supposes.

2. That the neutral axis always remaining at the centre of gravity of the beam, the additional strength is due to the *adhesion* of the fibres which is developed by the unequal lengthening, and shortening of them as we go from the neutral

axis towards the surfaces. In favor of this view is the fact that we know such adhesion to be an element of strength; for the compression or extension due to a given force is not so great in a transversely loaded beam as in one directly compressed or extended.

The action of this adhesive force may be illustrated as follows :

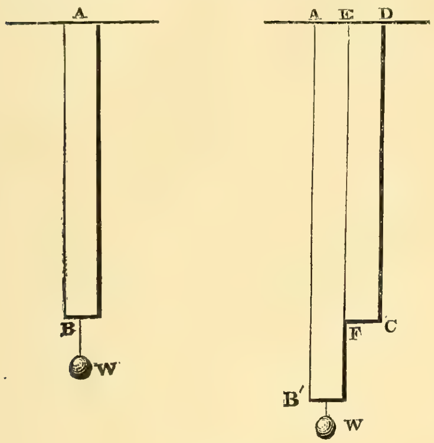

FIG. 46.

In the beam A B (Fig. 46), strained by the weight W, all the fibres are equally elongated, and they only resist by their direct tenacity. But in the beam A′ C to the one-half of which is appended the weight, while the other half, E C, is less strained or altogether prevented from extending, evidently W will have to overcome not merely the tenacity of the fibres in A′ B′ but the adhesive force of the fibres along the plane E F, where the two parts of the beam join; for this force will tend to prevent the stretching of the fibres in A′ B′, and consequently increases the strength of A′ B′. This kind of force exists between every two layers of horizontal fibres in a beam under transverse loading, and is called the *longitudinal* shearing stress. It is neglected in the formulae we have given.

From the variation between the ultimate valves of S (called *moduli of rupture*) and the values for strength obtained by direct tension and compression, it results that the values should be determined in both ways, and that the values gotten by one method should not be used in calculations involving the other kind of stress.

BEAMS OF UNIFORM STRENGTH.

As already stated, in solid rectangular beams, S has different values for the various points in the length of the beam. There is always a point of maximum stress where the beam, if loaded sufficiently, will break. Now at all other points there is an excess of material which is useless and injurious from its own weight. To secure the requisite strength with the least material is an object usually desirable, and this can be readily accomplished in certain materials (as cast-iron), by giving the beam such a shape as will make S, the stress on the outside fibre, constant throughout its length. In wood the injury resulting from the cross cutting of the fibres frequently prevents the putting of the theory into practice.

The application of the theory of uniform strength to beams of *rectangular cross section* may be most simply explained by taking up the cases we have discussed in detail.

In *Case I.* from eq. (5) the maximum stress in the outside fibre is,

$$S = \frac{6\,W\,l}{b\,d^2} \qquad (51)$$

This stress only occurs at A, where the beam will ultimately break, and it is evidently possible to take away some of the material between that point and

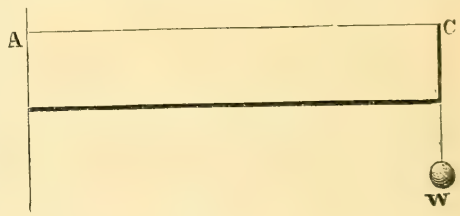

FIG. 47.

C without diminishing the strength. If this be so done that at every point between A and C there shall exist on the outside fibre a stress equal to that at A, the beam will be one of uniform strength, and we shall have attained the greatest economy of material. Let us suppose, the use we have for the beam requires the depth to be uniform. What must be its *plan* in order that S shall be constant in value, or the beam be as liable to break at any other point as at A?

In eq. (4) $S=\frac{6 W x}{b d^2}$, if we assume S to be constant, the other side of the equation must be constant also, and since $6 W$ is constant, and we have made d constant by assuming the depth to be uniform, the whole expression can be constant only when b varies as x.

$\therefore \quad b \propto x$ whence $b=c x$ (where c=some constant factor). This equation which is that of a straight line shows that the breadth must vary directly as

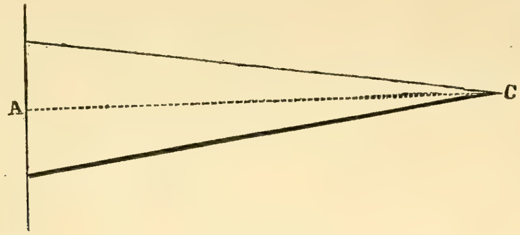

FIG. 48.

the length. Hence the *plan* should be a triangle with vertex at C (Fig. 48.)

On the other hand, if we suppose the breadth to be uniform and wish to have S constant, in the eq. $S=\frac{6 W x}{b d^2}$, x must vary as d^2, or

$$d^2=c x$$

This corresponds to a parabola, and the beam, if the top be straight will have the *elevation* shown in (Fig. 49).

Suppose that b varies as d, then $d=n b$ (n being a constant) and

$$S=\frac{6 W x}{n^2 b^3}$$

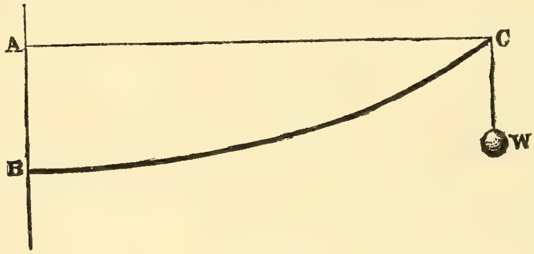

FIG. 49.

To render S constant we must have, $b^3 \propto x \quad \therefore \; b^3=c x$ and $d^3=n^3 c x$.

These are the equations of a *cubic parabola*. Hence the horizontal section (Fig. 50), and the vertical section (Fig. 51), should be curves of that kind. The

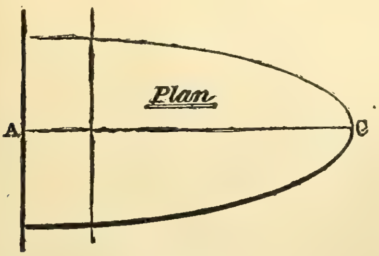

FIG. 50.

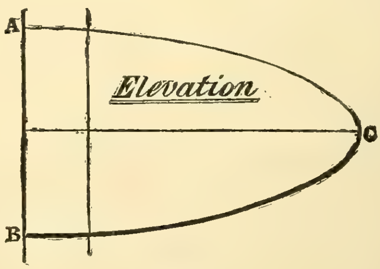

FIG. 51.

cross section is rectangular as in (Fig. 52).

In *Case II.* we have

$$S=\frac{3 W x^2}{b d^2} \tag{55}$$

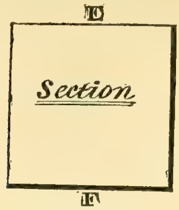

FIG. 52.

Hence, if we make suppositions similar to those above we shall have, when the depth is uniform (or $d=$ a constant) x^2 varying as b, or

$$b=c\,x^2$$

Hence the *plan* (Fig. 53) should con-

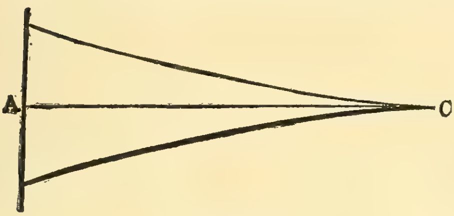

FIG. 53.

sist of parabolas with vertices at C. If b be constant then

$$d^2=c\,x^2 \quad \text{or} \quad d=\sqrt{c}.\,x$$

This is the equation of a straight line, and gives for the *elevation* the triangle (Fig. 54).

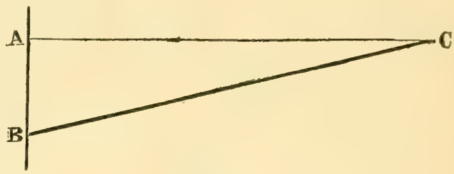

FIG. 54.

In *Case III.* the analysis gives results similar to those in *Case I.*

Thus from equation (21) $S=\frac{6\,W\,n}{l}.\frac{x}{b\,d^2}$. Here $\frac{6\,W\,n}{l}$ is constant, and if d be constant also, b must vary as x.

$$\therefore \quad b=c\,x.$$

This gives the triangle A G H (Fig. 55). We obtain similarly the triangle G C H for the other end of the beam.

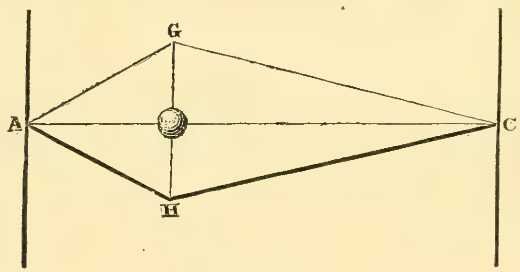

FIG. 55.

If the breadth be constant we have,

$$d^2=c\,x$$

which gives a parabola AK (Fig. 56) with vertex at A. So, for the right hand end of the beam the proper elevation is the parabola C K (Fig. 56). The elevation (Fig. 56) assumes that the top of the beam needs to be horizontal.

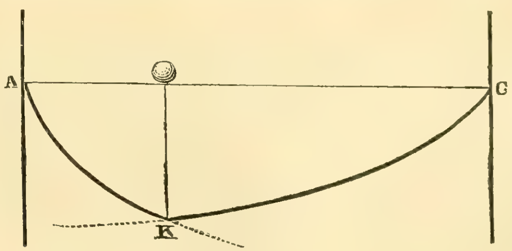

FIG. 56.

In *Case IV.*, equation (37) gives $S=\frac{3\,w\,x\,(l-x)}{b\,d^2}$: Here, if d be constant in order to render S constant we have

$$b=c\,x\,(l-x).$$

This may be represented by parabolas with vertices at G and H (Fig. 57) opposite the middle of the beam. If b is constant, then,

$$d^2=c\,x\,(l-x)$$

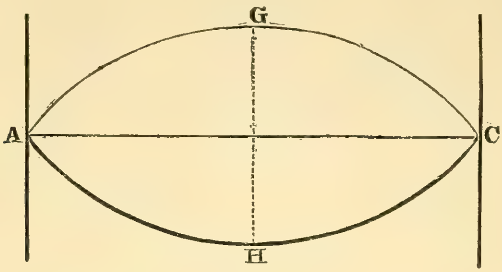

Fig. 57.

which is the equation of an ellipse, and the beam (if it is required to be horizontal on top) may be made as in (Fig. 58).

In these cases of beams of uniform strength, we have so far only considered the *moments* of the weights or the *bending moments* as they are called. But the

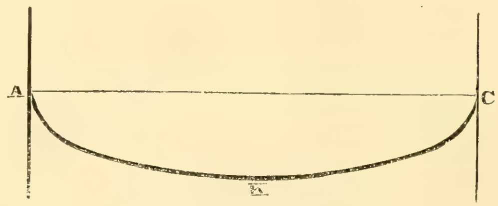

Fig. 58.

results are to be modified by the transverse shearing stress. In ordinary rectangular beams this shearing stress is so small compared with the bending moment, that it may be left out of consideration. But in beams of uniform strength the ends must not taper to a point, but must always be left large enough to bear the shearing stress. In the case represented in (Fig. 57) the beam should have, near the ends, the shape shown in (Fig. 59).

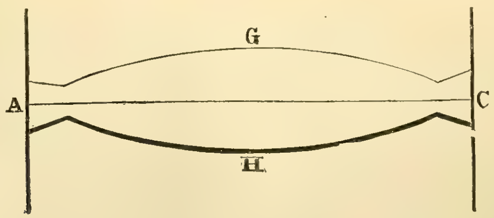

Fig. 59.

ON THE USE OF COIGNET BÉTON "*EN MASSE.*"

Condensed from Chief Engineer CHAS. K. GRAHAM'S Report to the "Department of Docks."

The Canal Street section was commenced on the 4th of May, 1874, by driving piles for new Pier 34, the present Pacific Mail Steamship pier. It springs from the bulkhead wall, almost in a direct westerly line from the small pier formerly known as 42½.

The bulkhead wall on this section, 110 feet of which has been finished, foundation up to stone facing for a distance of 80 feet built, and pile work for 60 feet more ready for concreting, is a subject on which I will have to dwell at some length, as the method of constructing it differs materially from that used at the Battery and Christopher Street sections. At the latter works the system was—to drive piles, cut them off at a fixed distance from mean low water, and upon them to place prepared beton blocks by means of 100-ton derrick and divers.

On this section, as well as the King Street section, the piles are punched down, and loose concrete laid *en masse* in a false work of timber, which is subsequently removed.

That eminent authority, Mr. Thomas Stevenson, in his work on the "Design and Construction of Harbors," at page 201, says: "Sir John Hawkshaw has passed concrete through 50 feet of water with perfect success. As far as his experience went, the concrete set quite as well under these circumstances, as when it was deposited in the open air. He has done this both in salt and fresh water. In passing concrete through water, he used a box containing almost 2 cubic yards; when it reached bottom, a bolt was withdrawn, and the concrete dropped out."

The same authority, on page 202 of the same work, also says: "Mr. W. Parkes put in the foundation of the iron light-house in the Red Sea by means of a caisson into which the fluid concrete in bags was deposited." He thus describes the method of construction: "During this time some progress was made at the light-house works. The caisson of iron-plates to enclose the concrete base had been deposited upon the reef, where it was exposed to a wash sufficient to remove some of its clayey particles, without carrying it out of reach. As soon as a sufficient quantity of gravel was accumulated, the process of depositing the concrete was commenced. As circumstances did not admit of the usual plan of depositing the concrete in the water in large masses from boxes, the following plan was substituted: Sheets of tarred canvas were prepared of such sizes as would fill up the spaces between the piles, and allow 2 feet round each side, to be turned up, so as to form large shallow bags. The edges of the tarpaulin were then lashed to the wooden rods, which were slung to the piles, so as to allow the tarpaulin bag to float slackly on the surface of the water. Two or three hours below low water the work was commenced. The concrete was mixed in the lighters moored alongside the caisson—6 measures of gravel being used with one measure of cement, and a suitable quantity of water. The materials were thrown into the centre of the canvas bag, which gradually sunk to the bottom (generally from 1 to 2 feet under water), and the bag was spread out evenly over the whole area as it became filled. This was continued until the tide rose nearly to the level of the top of the deposited concrete, when the sides of the tarpaulin were drawn close over the soft mass, and lashed tight. In this way blocks of from 6 to 14 tons were deposited without the material having been subjected, in small quantities, to the action of the water. The blocks were generally hard enough on the following day to allow of the exposed parts of the tarpaulin being cut away; and so complete was the set, that casts of the cords and the edges of the tarpaulin were often sharply impressed upon the face of the concrete."

At the Canal Street section, the joints of the caisson were so close, as to admit of scarcely any wash, and being in a slip with block and bridge piers on either side, the current was scarcely perceptible, consequently when the concrete was

deposited, little more "laitance" or milkiness was visible than would have been occasioned if fresh made beton blocks prepared on land had been immersed in water. That eminent marine engineer, Sir Charles Hartley, in his valuable report on the "Delta of the Danube," at page 39, says: * * * "and the absence of divers to execute the work, induced the author, at first, to adopt the plan of building the wall on a roughly leveled foundation, by carefully lowering down masses of unset concrete within movable timber dams, fitted in lengths of from 15 to 30 feet, to the framework of the piers. This plan was not adopted on a large scale, until it had been found, by repeated experiments, that the concrete, when made with a sufficient quantity of Portland cement, set perfectly hard on a rocky foundation in a seaway, although lowered through the water in a semi-liquid state."

In passing the cement through the water at Canal Street, two separate one-yard tubs were used, and the concrete mixed was comparatively dry and far from a semi-liquid state.

At page 41 Sir Charles further says: "The spaces between the beton blocks used were filled up with newly made concrete, which, searching its way under the adjacent blocks, and filling in the grooves, moulded in their sides expressly to this end, caused the whole mass to become ultimately as solid as if it consisted of but a single stone."

As to the strength of the Portland cement used, Sir John Coode, in his remarks from Hartley's description of the "Delta of the Danube," at page 74, says:

"The cement was tested by Grant's machine to resist a tensile strain of 350 pounds per square inch, after being immersed in water 7 days. He had made large quantities of cement in mass under water and at a considerable depth, with the proportions of 1 of cement to 5 of gravel; he had executed a large amount of such work for some years past, and had built a substantial sea wall to the height of 40 feet upon it."

The proportions used at Canal and King Streets are almost identical—1 of cement, 2 of sand, and 5 of broken stone. At page 76, same work, Mr. Coode says: "He had lately put down some foundations for a heavy sea work on a rough, rocky surface, where, if he had not deposited the *concrete in mass* upon the rock, the expense of preparing the bottom to receive the blocks would have been somewhere about twice or three times as great, and the time occupied would have been three or four times as long as was required to execute the works by means of concrete deposited 'in situ' upon the bottom in 16 feet of water at the lowest spring tides."

I further give some excerpts taken from the reports of the Institute of Civil Engineers, London, Vol. 1862–3, a paper by Daniel Miller, C. E., entitled "Structures in the Sea without Coffer Dams:"

"The system of building under water by means of diving-bells and diving-dresses has been practised to a considerable extent; and the improved apparatus, now used, gives great facilities for this kind of work; but it is only applicable under particular circumstances, and it is also *costly*, besides being liable to cause delay in the progress of the work."

"There are three modes in which concrete may be applied for constructive purposes — building it in mass and allowing it to set before water has access to the work, as has been adopted in the construction of the walls of the Victoria Docks by Mr. Bidder, and in those of the London Docks by the late Mr. Rendel—preparing it first in blocks and allowing it to harden before being used, as employed by the late Mr. Walker, at the Dover Breakwater, and by Mr. Hawkshaw for the new sea forts for protecting the arsenals of Plymouth and Portsmouth—and depositing it in a liquid state, and allowing it to set under water, as practised upon a gigantic scale by Mr. Noel in the construction of the large Government Graving Docks, at Toulon. In the latter case, hydraulic concrete has been deposited in a liquid state in the sea water at a depth of about 40 feet, forming a vast rectangular trough of beton about 100 feet wide, of the length of each dock respectively, and with walls and bottom about 16 feet thick."

Speaking of the various kinds of hydraulic limes, Mr. Miller says: "It may be useful to mention, for comparison, the proportions of some of the concretes made from these various limes. The

Arden lime concrete employed by Messrs. Bell & Miller for the foundations of the large Graving Docks at Glasgow was composed of 1 part of ground Arden lime, 1 part of iron mine dust, and 4½ parts of gravel and quarry chips. The *lias concrete* used at the recent extension of the London Docks by Mr. Rendel consisted of—1 part of blue lias lime to 6 parts of gravel and sand. The proportions adopted for the blocks of the Mole at Marseilles were 2 parts of broken stone to 1 of mortar, the latter being composed of 3 parts of Tiel lime to 5 of sand." * * * * * "The Portland cement used at the new Westminster Bridge is harder and more compact than the greater number of building stones, even where put down in the bed of the Thames, and where it is exposed to the running stream." * * * "The author had lately an opportunity of examining at Genoa the extension of one of the Moles of the *harbor*, the inner side of which has a vertical wall."

"The latter was in process of being constructed *under water* entirely of pozzuolana concrete, simply thrown into the sea from baskets, carried on men's heads, a boarding confining it to the shape of the wall. In a short period it set quite hard, so as to enable the upper part of the wall, which is of stone, to be built on it." * * * * * "Though the depth of the quay wall was not great, this shows the confidence which the Italian engineers have in concrete applied under water in a soft state. The piers of the new basin constructed by the Austrian Government at Pola, in Istria, are also formed in a similar manner, of concrete, confined between rows of timber piling. But perhaps the most striking application on a large scale of pozzuolana concrete, is in the great Mole which protects the port of Algiers. To form the Mole, blocks of beton of immense size, so as to be immovable by the force of the sea, were employed, some of these formed '*in situ*,' by pouring the concrete into large timber cases without bottoms, sunk in the sea in the line of the Mole."

"Hydraulic concrete, to be effective, requires great care and attention in its manipulation and in the regulations of the proper proportions of its materials."

"*Any failures must have arisen* from inattention to these or similar points, as there is ample experience to show, that when properly made, every confidence may be placed in the strength and durability."

In the construction of the Albert Harbor, Greenock, the following occurs, same authority: "The mode in which the work was designed was to form the walls under low water, of a combination of cast-iron guide piles in front, with a continuous stone facing, slid down over and inclosing these, and of concrete backing deposited in a soft state, all of which could be easily accomplished from above the water line." * * * * This plan was felt to be so novel, particularly as regards the concrete, that, though the trustees as a body had the greatest confidence in the engineers (Messrs. Bell & Smith), they considered it to be their duty, before proceeding with the work, to fortify themselves by having the opinion of another engineer; accordingly Mr. Thomas Page, M. Inst. C. E., was consulted, who fully satisfied them as to the efficiency of hydraulic concrete applied in the manner proposed, and otherwise confirmed the soundness of the principles upon which the works were designed.

Again, same authority: "Immediately after being mixed, and when brought to a proper consistency with water, it is conveyed to where it is to be used, is let down under water in the discharge boxes, and in a short time sets very hard. * * * This mode of constructing walls in deep water, without coffer dams, has proved very successful, and a sea pier of great solidity and durability has been formed at a comparatively moderate cost." * * *

"Temporary sheet piling or boarding, instead of loose stone, may be employed to keep the concrete in its place until it has set."

General H. G. Wright, of the United States Engineers Corps, an officer of great experience, in a letter addressed to Major-General Hamilton, late Superintendent in Charge of Yards, on the subject of Rosendale cement, among other things, says: "Of this cement I used some 50,000 bbls. in the fort at the Tortugas, a large part of which was for foundations and walls under water; the particular blocks to which I referred

were laid to test *the workings of the tremie.* * * * * They were laid in 1848, I think; and when I left in 1856, they were in as good condition as when laid, the surfaces being apparently as perfect. The concrete was made with sea water, no fresh water having been used."

In a subsequent statement, more particularly on the working of the *tremie system*, made lately, that eminent officer said: "The success attending (the above) induced him to construct the foundation of several of the forts in Southern waters in a similar manner, and with like success."

Forts Jefferson and Carroll he cited as prominent examples. "* * * * Should not hesitate to construct foundations under water, by depositing liquid concrete *in mass*, if care was taken in its manipulation."

Besides the valuable experience of General Wright, as above detailed, to my own knowledge mass concrete has been used in this country in the construction of foundations below water for a period of twenty-five years at least.

While Engineer of the Brooklyn Navy Yard I constructed a wall *en masse*, which is a standing witness to-day of the success of the system. My predecessor in office there used somewhat similar means. Mr. McElroy's wall at the Wallabout would have proved a success if attention had been given to the placing of more piles in the foundation, and had the Rosendale cement used, retained its previously high character, and not deteriorated in its tensile strength.

I will now briefly describe the method of placing this mass concrete *in situ* on the works in question.

The wall, up to within 2′ 2$\frac{7}{16}$″ (two feet two and seven-sixteenth inches) of mean low water, is made of a huge monolith of concrete *en masse* manufactured on the spot and deposited *in situ.*

The site for the wall was first thoroughly dredged to a mean depth of 20 feet below mean low water; piles were then driven, 8 in a cross section of 17 feet 6 inches, and of an average distance of 2 feet 6 inches from centres, except the two front rows, which are centred two feet; longitudinally the outer and inner rows were driven as close as could be done without interference; they were punched to about a mean distance of 13 feet below mean low water, by means of a heavy oak follower 26 feet in length and 12 inches in section, armed at the bottom with an iron pintle and banded with iron to strengthen against fracture; this punching obviated the cutting off of any other than the westerly row, and those only for a distance of 180 feet; this uneven punching afforded a good grasp to the concrete around their heads. Broken stone, measuring about 4 cubic inches, was then filled in between the piles and allowed to take a bearing. The false work for receiving the concrete was then erected. Yellow pine square piles, 12 inches by 12 inches in section, and of an average length of 40 feet, were driven in front of the westerly row of punched piles at a batter of 1$\frac{3}{4}$ inches to the foot, and on the back at a batter of $\frac{1}{2}$ inch to the foot, centred longitudinally 8 feet; to the inside of these square piles, previous to their being driven, battens of 4 inches by 2$\frac{1}{2}$ inches spruce were nailed on firmly, and on these further pieces of spruce, 12 inches by 2 inches, were fastened, forming grooves for receiving constructed wooden shutters or gates which were slid into place after the pile alignment was perfected. These piles were then capped crosswise by square 12-inch timber, braced laterally by waling pieces 12′×6″, and on these cross caps stringers were laid, on which were placed rails of flat iron to receive the wheels of a movable platform car, bearing on it a 10 horse-power engine for the lowering of the concrete into the caisson. This platform car had erected on it a gallows frame holding traverse wheels with pendant bales of iron, from which were suspended double block purchases for the lowering and hoisting of two separate 1-yard buckets, each working from a separate drum independent of the other, so that one bucket could be lowered while the other was filled.

The concrete was mixed on a platform in the rear, constructed on the stay piles driven in the rear of the wall, wheeled to the car, dumped into the buckets or tubes, and then lowered into the caisson. The door of the bucket being opened from above by a trap rope, did away with the necessity of employing divers, and the only occasion when divers were

used at all was when Mr. McDonald, foreman of masons, himself a practical driver, leveled off the top layer of concrete to receive the granite facing. The buckets could be shifted from above in such a manner as to command any portion of the bottom.

The proportions of the concrete varied occasionally, but the usual proportions were, as before stated, 1, 2, and 5, or 1 part cement (Portland), 2 of sharp sand, and 5 of small broken stone.

Concreting was commenced on the 24th of December last and continued until the 6th of January, 1875, a layer of two feet being spread over the bottom, soaking into the broken stones at the bottom, and binding the pile heads firmly together. The quantity of ice by this time proving very troublesome, concreting was suspended until the middle of March (though further piling for the wall was continued throughout the winter, with scarcely any intermission), and vigorously prosecuted until the end of April, when the whole mass necessary was placed. In the hearting of the caisson, one-fifth of granite spawls, from the Departmental Stone Yard, were placed and thoroughly grouted, preserving the stability of the wall and lessening the expense.

In placing the concrete in water, chilled sometimes to 3° colder than the freezing point of fresh water, some means had to be adopted to counteract its chilliness. That eminent and versatile engineer, Mr. Chanute, in his report on the Kansas City Bridge, says:

"Both masonry and beton were laid in extremely cold weather, the use of hot sand and water being found to make this practicable. The sand was heated in large sheet iron braziers, and the water warmed in cast-iron kettles, one of each being found sufficient to supply the force working on a pier. The heat which was thus artificially given to the mortar hastened its setting, causing this to take place before the mass had cooled enough to make freezing possible."

Mr. T. C. Clarke, in his able and exhaustive report on the Quincy Bridge, says:

"During this time the glass fell as low as 16° Fahr. A shanty was built on a flat, and in this a kettle was placed on a stove, and the cement mixed with hot water. During the coldest days each stone was, before being set, held over a brazier of charcoal to draw out the frost. The mortar was examined carefully in the spring, and found to be as hard and perfect as any on the work. Much of the masonry of this bridge was constructed during winter, although none in as cold weather as this pier, *and there is apparently no difference in the quality of the mortar* whether built in *winter or summer*."

As the quantity of cement used by these gentlemen was very small in comparison with that which would have to be used in the bulkhead wall in question, some means had to be taken of a more extensive nature. For heating the water, the following simple apparatus was used. A cask capable of containing 60 gallons of water, holding a coil pipe, was placed on the movable car, and through this coil the steam from the boiler of the engine was passed at will; this heating was done very rapidly and efficiently, it only taking from 4 to 8 minutes to heat the whole 60 gallons from 32° to 100° Fahr., the water thus heated being carried to the mixing platform by india-rubber tubing. To heat the sand and broken stone, heaters made of iron, similar to those used in street paving, were constructed by Mr. Joseph Edwards, 414 Water Street, New York, each capable of heating a cubic yard of material, the fuel used being old barrel staves, &c. They did their work thoroughly, and by this means work was carried on, on one occasion when the temperature of the air was 11° Fahr. and that of the water 32°, the concrete becoming as hard as if made during the hotter summer months, thus practically substantiating the opinions of Messrs. Chanute and Clarke.

In laying the backing to the granite facing I have introduced a change from that at Christopher Street section, which has materially lessened the expense, while preserving the stability of the wall. Blocks of about three cubic yards capacity were made at the Seventeenth Street yard out of old granite spawls and Portland cement; when sufficiently compact they were transported to Canal Street, and placed in position with great rapidity, over 70 lineal feet being laid during one tide. The success attending the use of these rubble blocks has been

such that I have recommended to the Board in my report on the "Development of the Harlem River and Spuyten Duyvil Creek for Commercial Purposes," that the bulkhead wall when constructed should be composed of beton placed *en masse* with a rubble masonry facing surmounted by a granite cope.

On the removal of the shutters and square piles—the false work of the caisson—which had been down nearly three months, Mr. McDonald carefully examined the sides of the monolith and reported that he found it as smooth and compact in appearance as any blocks he had ever seen which were manufactured on land—and no sign of honey-comb. This assertion was verified by my assistants, who passed a boat hook all along the sides both front and rear, and found it as smooth as the Gansevoort Street manufactured blocks; the edges of the "berme," too, 6 inches in width where the stone facing springs from the monolith of concrete, was as distinctly defined as that of a well cut piece of granite. A great saving has been effected by this system of construction, over that of the block system, including coping not as yet required on this section (the wall constructed being in the wake of the pier); the saving amounts to $67.77 per foot run, or over $350,000 per mile, the cost per foot run being $311.67.

By having a long stretch of work, a judicious use of labor, and using made rubble blocks surmounted by granite scope, instead of cut facing, I am of the opinion that the cost can be reduced at least 20 per cent

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Since this report was written, the Canal Street section has been extended about 200 feet, the short section at the foot of King Street completed, and a new section commenced at the foot Clarkson Street. The plan of construction being in every case precisely similar except on the Clarkson Street section, where it has been deemed advisable, in consequence of the great depth and softness of the mud, to drive the two front rows of piles with a batir of $1\frac{3}{4}$ inches, instead of perpendicularly, as on the other sections; the object of the change being to oppose still greater resistance on the part of the foundation to lateral pressure, and to enable the mould boards to be slid down further, so that the concrete may bind the pile heads to a greater depth.

The advantages of the beton "en masse" system are:

1st. As many sections as the Department deem advisable can be in course of construction at any one time—the distance between the old piers enabling the work to be prosecuted in the slips without any serious hindrance to commerce.

2d. The work, by the adoption of the heating process, as applied to water, sand, and stone, may be prosecuted at least during nine months out of the twelve.

3d. Unskilled labor can replace to a very great extent the skilled labor required under the block system.

4th. The new piers being differently spaced from the old, these new piers may be projected from the new bulkhead wall and completed in a great many instances before it becomes necessary to remove the old ones.

5th. The rapidity with which the work may be prosecuted and the immense saving in its cost.

The Drainage of the Thames Valley. The City Solicitor announced to the Hampton Wick Local Board that a letter had been received from an inspector of the Local Government Board, stating, in reference to the subject of a combination of sanitary authorities in the Thames Valley for the purpose of carrying out a joint scheme of sewerage, that it was proposed to hold a conference in London, and asking that two or three members of the board might be named as delegates. Messrs. Frere & Co., of Lincoln's Inn Fields, had also written, stating that they were instructed to take proceedings against the Local Board of Hampton Wick for a disregard of the notice to discontinue the flow of sewage into the river Thames. Mr. Nelson thought this letter from Messrs. Frere could not have come at a more inopportune moment, and suggested they should be informed that a commission was issued by the Government, and that under the circumstances the Conservators had better abstain from any proceedings, which the board were prepared to meet.

NEW MATERIALS AND RECENT INVENTIONS CONNECTED WITH BUILDING.*

From "The Architect."

The subject I have the honor of introducing to your notice is necessarily full of details, and when once we have plunged into these it is not likely we shall be able to quit them for generalities. I therefore ask you to permit me to lay before you such general considerations as seem to belong to it now at the outset, rather than to reserve them till the close of the paper.

The first remark that will occur to most observant men is, that the building art, as conducted in England at the present day, presents fewer novelties than almost any others of the leading technic processes. Steam, electricity, and the progress of mechanical inventions and chemical research have revolutionized most of the great divisions of human industry. Sometimes it is a new method of manufacture which has supplanted an old one—the material remaining unchanged. Sometimes the old material has given way to a new one, and not unfrequently both material and method are alike revolutionized by discoveries made through that restless and eager spirit of inquiry and invention which is perhaps the chief glory of the present century.

For examples of new methods of employing old materials, we may turn to the principal fabrics used in clothing. Wool, flax, cotton and silk, are what they always were; but spinning, weaving, dyeing and ornamenting, which once were handicrafts, are now mechanical processes carried on by steam machinery in vast factories. Printing is another example of the same change; paper, ink and type are still employed, but the contrast between the handpress—which within the recollection of many of us was the only method in use—and one of Mr. Hoe's magnificent steam machines is enormous.

Of new materials which have supplanted or supplemented old ones, a very long list could be made out. One or two will suffice for the purposes of an illustration. Various grasses and other substances have now come into use either along with linen rags or as a substitute for them in the manufacture of paper. Stearine and various similar products have almost displaced wax, spermaceti, and even tallow as material for candles. Mineral oil has largely displaced fish oil. We are using stamped and printed paper for window curtains, and printed cloth for embroideries, German silver instead of plate, and papier màche in place of wood; and in a hundred other instances the craftsman has a constantly increasing series of new substances placed within his reach by the scientific discoverer.

The most remarkable cases of all are, of course, those where material and method are both alike new, having either been called into being to supply some new want, or else presenting themselves with such capacities for being useful or pleasant inherent in them, that a want has sprung up, after the power of supplying it was acquired. All the applications of photography, of the electric telegraph, of the spectroscope, and of our amazingly enlarged chemical knowledge, seem to belong to this head. Till we knew we could have them our wildest dreams never led us to desire such things as photographs of our friends, or telegraphs from them when at the antipodes; and such contrivances as the sewing machine, such materials as gutta percha, or such inventions as the locomotive, have brought into existence a whole range of new requirements, which the world had never dreamed of till the power of supplying them was called into existence.

Building, compared with such matters as locomotion, the manufacture of clothing, or the transmission of intelligence, is an art which has changed wonderfully little, so little indeed that I am sometimes tempted to believe that there still remains open to some inventive genius among ourselves, the possibility of effecting something like the revolution which Arkwright commenced for textile fabrics, when he applied steam power to spinning. It is, of course, natural to say

* From a paper read before the Royal Institute of British Architects, by Mr. T. Roger Smith.

that it cannot be done; but the same thing might have been said beforehand of all the great steps which handicrafts have taken, and we might, I believe, do worse than entertain very seriously indeed the possibility of adapting machinery, mechanical processes, and novel combinations of material to building, on such a scale and in such a way as to cheapen the cost of simple plain structures to a great extent. This subject would land us at once in a region of speculations which might prove of practical advantage, and to us I confess the subject is tempting in the extreme, but I have not any intention of inviting you to pursue it. If, however, a wholesale transformatian, such for example as would be effected were we prepared to abandon brickwork for concrete, and slates for felt, is not within our reach, there are available for use no small number of inventions, in which the progress of contrivances and discovery has told upon the resources at the builder's disposal; and it is some of these which we are to consider.

Granted, then, that there exist a certain number of novelties, my second preliminary observations must be directed to the position which the architect ought to take with regard to them. This is a question which has two sides. It may be said that the architect as the skilled, cultivated, and trained director of the work, is bound to know what is going on, to make himself familiar with the latest improvements, and to give his clients the benefit of his knowledge; in short, he is to be abreast of the building art in his own day, and is to show that he is solely making himself acquainted with each capital invention as it comes out, and to embrace every opportunity of using it. This is a position which has much to be said in its favor. And if men expect their doctors to know the latest medicines, and their lawyer to be acquainted with the most recent legislation, they may be excused if they ask that their architect shall be equally well posted. If, however, you ask your medical man whether if some new remedy of which you have heard is not said to suit your symptoms, he will probably reply: "Yes, but I doubt whether it would suit your constitution; the reports of its actions are by no means uniform or complete, and if you take it you will be trying an experiment." Your solicitor when you ask him to take proceedings under some new Act will, if he be prudent and honest, reply: "True, the language of the Act seems to fit the case, but it has not yet been tested before the Courts, and your case will be the one to fix the interpretation upon the language if you proceed under this Act; better be cautious."

In both instances the professional man, if he had no duties to his client, would be delighted at the opportunity of contributing to the fabric of professional experience an item possibly of much importance; the expense or distress of the process being borne by the vile body—or purse—of his client. But if he is true to that maxim of professional conduct—which I take to be a sound one, so long as it does not carry a man beyond the limits of honor and good faith —"do the best you can for your client" —the experiment is left for some one else to try, while better known and safer methods, supposing such to exist, are adopted, even if they be less brilliant. This I hold illustrates an architect's true position in regard to new inventions. He ought to make himself familiar with them all; he ought to neglect no advantage offered by them; but he has no business to try experiments at a client's expense. If this be true there are only three conditions under which an architect is at liberty to adopt a novelty. First—If it has been in some way put beyond doubt that the novelty will succeed; Second—If it is certain that received methods will not succeed, and the novelty offers a better chance; Thirdly—If the client, knowing that there is the possibility of failure, decides that the novelty shall be tried.

It may be said that these conditions very much limit the adoption of new inventions, and no doubt they do so; but I hold that our first duty as architects is to secure that our buildings shall answer their purpose, and that trying experiments in them is not justifiable except under conditions which either render failure impossible, or at least shift the entire responsibility on to other shoulders.

It now only remains to guard you and the readers of this paper against any

misconception as to its nature and scope. I do not claim to have hunted up and named all the inventions worth notice brought forward during the past few years. Still less do I claim to have selected the best. I shall not attempt to do more than to point out the directions in which invention has been chiefly exercised, and to give under each head a few specimens, selected not as the best but as the most convenient illustrations. The subject, thus looked at, seems to divide itself into (1) new materials, (2) new methods, (3) new structures, and (4) new appliances. New materials may include revived ones, and applications of known materials to new purposes. New methods refer to new modes of working, chiefly to the substitution of machinery for manual labor. New structures, hardly perhaps, need explanation, but must, of course, be understood as applying to structures of hitherto unknown sorts, and which from their novel nature are essentially new inventions; or new introductions. New contrivances will embrace those appliances which forms portions of our buildings, such as lifts, bells, or cooking apparatus; and also will include some few new combinations of building materials for special purposes.

New or Revived Materials.—of these the most important by far are iron and glass. The modern application of both to building has been well known to us now for a quarter of a century; in fact ever since the Exhibition of 1851 showed how rapidly and cheaply vast structures of iron and glass (the iron work being chiefly cast) could be erected, and how great a charm they possessed; and the applications of these materials have been numerous and varied. The leading principle upon which that building depended, and to which it owed both its architectural quality and its constructional success was the continued repetition of a small number of well-considered forms. Every pane of glass was of one size, and so upwards as far as possible. Every column was of the same length, and every girder was of the same span. This principle was adhered to in the design of the Sydenham Crystal palace, but it has been in some other instances over-looked.

An iron and glass building is no doubt not a very durable one, nor very weather-tight, and the expense of its maintenance will be considerable; but nothing is in first cost so cheap, and for the purpose of large gatherings of people, nothing so appropriate.

Treated in a different way, iron ribs, carrying some light filling in, which may be glass or wood, have enabled us, when we enclose enormous spaces in a more permanent manner, to roof them over. The great railway sheds, and such buildings as the Agricultural Hall, the British Museum reading-room, and the Albert Hall are examples of buildings having iron roofs of prodigious span. These are buildings such as, from time to time, come within the ordinary scope of an architect's practice. It is very desirable for us to obtain a familiarity with the principles upon which these roofs are constructed, as although it may be very wise to obtain upon them the assistance of an engineer, whose whole time is spent in working out the details of iron work, the architect will find that he is at a great advantage if he can design their general forms himself. All these applications of iron as a building material seem, however, to shrink into insignificance before Mr. Scott Russell's Vienna cone; but this has been so recently described here by the inventor himself that I need not do more than refer to it.

Other applications of iron to construction are so familiar that I shall hardly be justified in referring to many of them among new inventions. I may, however, allude to Phillips's girders, as a contrivance which is still tolerably new. These are built up, as you are aware, by bolting two rolled iron joists together, and sometimes four such joists are combined with plates in addition to their own flanges, into one large beam. It is not easy to see the scientific ground upon which this combination (which places a very large amount of material comparatively near the neutral axis of the beam) can be advocated, but there is obviously a good deal of simplicity and handiness in the combination, and it is said to have good practical qualities.

Messrs. Moreland & Son, who are well known as skilled in the application of iron to building purposes, have contrived a description of fire-proof construction, in which they imbed a kind of slight bow string truss in the concrete, which they

fill in between large girders. This constuction is so far different from ordinary fire-proofing as to deserve to be mentioned. It was employed at the St. Pancras Hotel, and appeared to me, when I saw it being fixed there, to offer considerable advantages.

The next material which I propose to notice is one which has but resently been introduced, and may fairly, on that account, lay claim to the title of a perfectly new invention. I refer to selenitic mortar, the invention of General Scott.

This mixture I shall, I believe, correctly describe if I say that it consists of the ordinary ingredients of mortar—namely, lime and sand, though the sand is in larger proportions than usual, with the additions of a small quantity of gypsum (sulphate of lime), intimately mixed with the lime. This mortar requires to be mixed in a pug-mill very thoroughly, and when carefully prepared, will be found to have acquired, to some extent, the properties of a cement, for it sets rapidly, and when set it is extremely hard and tenacious. It is to the admixture of the gypsum that the rapid setting is due, but perhaps some of the general excellence of the material may be owing to its having been better mixed than usual. The Albert Hall was the first large building in which this material was employed; and while that hall was in course of erection I had repeated opportunities of noticing its admirable behaviour. The London School Board have latterly adopted it throughout their new buildings, and probably their architects may have met with varying results, considering the various builders who have worked for them; but there can, I think, be no doubt that, on a building of any magnitude and under proper supervision, selenitic mortar will be found to be a trustworthy auxiliary to the architect. Of the use of the same material for plastering I cannot speak so fully.

The adaptation of concrete to building walls, floors, and roofs, as well as the foundations, may fairly claim a moment's notice. Tall and Drake are two names best known in connection with it. As far as I am aware the use of lime concrete, which involves walls, etc., of considerable thickness, has not been much pushed. Portland cement concrete, a stronger material, capable of being used on thin walls, and having the property of hardening very rapidly, is more commonly employed. The different patents have for their object, when walls are to be built, the construction of troughs by the help of frames and movable boards or shutters. These troughs are the exact size of the wall, and the concrete is filled into them. When the material has set the trough is taken to pieces, refixed at a higher level, and the process is repeated. I am not disposed to believe that much economy results from building in concrete, except where the work is very plain and straightforward, and when little is spent on subsequent finish; but there can be no doubt that a wonderfully strong and tenacious material is obtained; and probably where the foundation is unquestionable, the materials good, and the supervision during the progress of the work thorough, a stronger building is erected—and one more proof against the attacks of weather than if brick were employed—and at a not greater expense.

Allied to concrete is artificial stone, and this, with the various panacea for arresting the decay of building stones, has of late retreated to some extent from the public view. It is happily very difficult indeed to make bad stone into good, and consequently most of the solutions and washes which have that for their object have proved unsuccessful. Not that there are not many of them which have a sound scientific basis, but the difference is very great between treating a specimen of stone in the course of a well-arranged laboratory experiment, and treating similar stone, built into a wall, perhaps saturated with wet, and exposed to all vicissitudes of weather, in the rough way in which, on a scaffold, even careful workmen will apply, what they call chemical stuff; and we cannot wonder that solutions, which are theoretically excellent, have often in practice failed to protect masonry. The artificial stone of Mr. Ransome is, I think, the only material called artificial stone which has held its ground; and I believe that under his more recent patents an excellent and durable substance has been produced, but in many cases, not at such a price as has enabled it to displace natural stone for plain work. Where elaborate work, such as

would admit of being produced in a mould, has been required, this material has, I am informed, proved both economical and satisfactory.

Another material which (while it is incorrect to call it a substitute for stone) can often be adopted as an alternative material, is that very old form of brick, known as terra cotta, the use of which has revived to such an extent as to stimulate the manufacture. Although terra cotta is not a new material in one sense, it is so in another, for it is only very recently that it has become possible to obtain it in such quantities, and of such varied quality, that it could be readily adopted by the English architect. He who would employ terra cotta must submit to a certain amount of limitation; he cannot deal with it as freely as he can with masonry. He must design his ornament long beforehand; he must, if possible, arrange for a large amount of repetition; he must so design his work that, if slightly warped in burning, the effect shall not be entirely spoilt; he must prepare for delay and trouble, and he, or some one for him, must draw out all profiles, etc., to a sufficient scale to allow for their shrinkage. But subject to these and other minor conditions terra cotta is an admirable material. When used in large quantities it is cheap; it is very durable; it can be obtained of beautiful color and texture; it is the most appropriate material to employ along with brick, and it admits of the introduction of great richness, and of the indefinite multiplication of a few pieces of artistically modeled work. It is to be hoped that the Natural History Museum, where Mr. Waterhouse is employing it on an extensive scale, will give a great stimulus to its use. In the various buildings of the department at South Kensington and in the Albert Hall, terra cotta has been extensively employed; and Mr. Barry's Dulwich College, and Mr. Christian's Insurance Office in Bridge Street, may be pointed to as other examples of its use.

Bricks themselves, and tiles have not furnished of late years many really new inventions. The damp courses, air bricks, shaped facing bricks, and roofing tiles of the ingenious Mr. John Taylor are, I have no doubt, known to all present. I do not recollect any other varieties of brick requiring mention here till we come to Pether's ornamental bricks, a variety available for use in surface decoration. These bricks have a pattern impressed on them, and being made of fine clay and well executed, have been often introduced lately into decorative work, and might with great advantage be more generally employed, as architects could readily design ornament appropriate to them.

The various sorts of flooring and encaustic tiles are no longer new, indeed they present one of the best possible examples of a new building material becoming generally so adopted as in a few years to grow perfectly familiar. A tile of German manufacture was, however, introduced into this country a short time ago which has not yet become very generally known ; it is in large slabs, and rather delicate tones of color seem preferred, though very elaborate decorations have been executed in it.

A comparatively new mode of employing tiles for the lining of rooms have been introduced by Messrs. Simpson, who have decorated the interior of many parts of Messrs. Spiers & Pond's "Criterion," in this manner. The tiles are placed together in their unglazed state, and a picture is painted upon them in suitable colors for firing. They are then taken asunder and put into the furnace, and then subjected to great heat and glazed. If this is successfully accomplished, the tiles can now be fixed against the wall of the room and present an absolutely indestructible decoration, which can be washed as often as it is needed, though from its high glaze it is not easily apt to catch dirt.

Mosaic—the most ancient of all the arts of decoration—has a claim to be named among the revived processes if not admissible as a new one. I shall not attempt to describe Salviati's most praiseworthy revival of glass mosaic, which has placed in the hands of our architects a method of executing surface decoration which, ancient though it be, is, I think, really knew to Great Britain in its application to vaults such as the Wolsey Chapel, at Windsor, or the vault of the Albert Memorial.

Other descriptions of mosaic, however, especially tile mosaics, if less sumptu-

ous, are less out of reach, on the score of cost, and deserve our notice as affording a means of executing original decorative work at a distance from the eye as well as near. The ornamental frieze round the galleries of the Albert Hall, executed in tesseræ of about an inch square, is a good example. Here only two or three tints of color were employed, and the mosaics were rapidly made, after the full size cartoon had once been completed, by placing the tesseræ on a tracing to a portion of the cartoon till a space of a certain size had been covered (about six superficial feet, I think) and then upon the back of the tesseræ Portland cement was applied till a stout slab was formed which admitted of being handled readily and could be hoisted up and fixed in place.

Another description of work approaching mosaic has been lately introduced to London, and is obtainable of Mr. Burke, of Regent Street—I allude to marble mosaic. This work is executed to a large extent out of smallish irregularly-shaped fragments of the material, of two or three tints, so laid as to produce the general appearance of a mottled ground, which gives relief to a few portions of brighter colors executed in more valuable marbles. When well done this sort of mosaic is very effective; it can be obtained at a very moderate price, and it may be expected to prove extremely durable.

We will now proceed to consider for a few moments the second head—new *methods*—not because the list of materials is exhausted, far from it; but because enough has been said to carry out my promise that I would name a few as specimens of the whole, in the hope that in the discussion your own sources of information will enable you to enlarge my list.

New methods need not detain us long. The building trade has not been revolutionized by the introduction of machinery as other trades have been, and it is really only in one or two of its branches that anything approaching to innovation awaits us. A remarkable attempt to introduce machinery into this production of high art work was made when the machines by which the woodwork of the Houses of Parliament was roughed out were designed. These, I believe, are now in the possession of Messrs. Cox & Son, and are still worked by them; but from various circumstances they do not seem to have become generally known or copied.

Machinery for dressing stone has been again and again attempted, and has been employed with considerable success. The contractor for St. Thomas's Hospital had a series of machines at work, partly employed in sawing up the stone and partly in dressing it; and one or two stone-dressing yards exist, or did lately exist, where plain descriptions of work are performed by mechanical means. The action of such machines is, generally speaking, that they bring a series of chisels, or tools answering to chisels, forcibly down upon the stone so as to imitate the action of a mason at many points at the same time. Usually the chisels are carried on the periphery of a wheel, though different arrangements are adapted by different inventors. Probably sawing can be done better by machinery than by hand, as well as cheaper. The plain dressing of surfaces, and even the moulding of them, is within the reach of machinery, but it is doubtful if it will be so well executed as a good mason would do it, especially if the stone operated upon were of uneven or unequal texture, and the more elaborate the work or the fewer the repetitions, the less advantage, generally speaking, can be expected from the machine.

Joiners' work admits of the application of machinery to a larger extent than masons' work, chiefly, if not solely, because it includes so much more repetition. In a first-class joiner's shop you now find a very interesting and complete series of machines, which render it possible to diminish the labor on joinery very largely. It is hardly necessary to describe these inventions at length; they may be seen at work in the establishments of our large builders, and no one who has watched their operation can doubt their efficiency in all ordinary work.

Here, perhaps, I may most appropriately introduce a reference to the contrivances for testing materials, which supply us with information as to their strength and behaviour under different kinds of strain. We have now in Mr. Kirkaldy's large and accurate machine a

testing engine of a power practically unlimited, and accurate to the extent of making single pounds of pressure, while it will admit specimens as large as forty feet in length. Here, then, we have a means of investigating the strength of building materials such as has not been previously at our disposal, and we have only ourselves to thank if our knowledge is not extended thereby.

Our third head need not detain us long. New *structures* are not so often met with as that the enumeration of them should fill much space; and were we to attempt more than an enumeration, a single novelty would claim the whole time at our disposal. A railway station, a Crystal Palace, a modern hospital on the pavilion plan, a cottage hospital, a monster hotel, an aquarium, a winter garden, a model prison, a workhouse, a block of model dwellings, a board school—each of these is a new structure, each embodies very modern ideas, and each of them requires to be studied with some care before it can be safe for an architect to venture upon it, and each is in fact a new structure. And first, every such modern building as a market, a town hall, an exchange, or a court of law, built to serve the same purposes as ancient structures, must in the present day be much more perfect and much more elaborate than was formerly necessary, and is in effect an almost new contrivance.

A year or two back we were threatened with an importation of Swedish or Norwegian buildings, which, so far as their employment in this country is concerned, would be new buildings. I refer to timber dwelling-houses. The publicity given to Mr. Vicary's importation of a timber house, which he erected in Devonshire, turned attention to the possibility of building very roomy structures of wood at a low cost. I have no means of knowing how far this house has been copied, but it does not seem to have led to many such experiments, or some of them would have been pretty sure to become generally known. It is not easy to see why this build of house should not be followed in sheltered situations in this country. No doubt careful examination would show that it has drawbacks, but for use as a country resort, a shooting lodge, or a hunting box, a timber house properly constructed ought to be fairly comfortable and cheap.

This leads us to another attempt at importation, this time from our own colonies, and due to the ingenuity of Mr. John Taylor, whom I have already had occasion to name, as a building inventor. I allude to the bungalows which that gentleman has erected near Westgate, and at Birchington in the Isle of Thanet. I have had the opportunity of seeing these houses, and of examining one of them in course of construction. They are very simple in shape, mostly, but not always, one story high, spanned by a simple low-pitched roof, portions of which are prolonged in the true Anglo-Indian style to form a verandah. These buildings seem thoroughly well adapted to the purpose for which they are erected—that of summer sea-side dwelling houses; they can be worked and kept clean with a very small amount of labor, as many contrivances to diminish servants' work have been introduced, and they are evidently cheap to build, though tasteful both outside and in. For the purpose of these buildings Mr. Taylor has invented what may perhaps be called a water-proof wall. This invention has been patented by Mr. Taylor, who is willing to grant licences to those who desire to use it.

Other new buildings are to be found now about watering places where a public room, more or less resembling the établissement of a French sea-side town, is often now to be found, and where also an aquarium or winter garden, and a pier with a pavilion at its head is now *de rigeur*. As, however, the Committee on Sessional Papers will, without doubt, see fit to obtain a descriptive account of some, if not all these structures, they need not detain us at the present moment; and the same remark applies to that strikingly new construction which the Safe Deposit Company have engaged our Fellow, Mr. Whichcord, to erect opposite the Mansion House.

In conclusion Mr. Smith enumerated various new building appliances, and regretted that he had been prevented by want of time from procuring a larger number of specimens for exhibition. Before an architect used any new invention he would naturally first inquire—How it would go wrong; secondly, if it went

wrong what would be the worst consequences; and, thirdly, whether failure was preventible? Upon the question of repairs, he pointed out that it would not be a fatal objection to the use of iron shutters if the manufacturer's works were 100 yards off; but it would be intolerable if they had to be sent 100 miles when they got out of repair. The position of the architect with regard to the use of novelties was a very responsible one, and Mr. Smith explained that his review of a very large subject had necessarily been very partial and incomplete.

Mr. Hebb said that he had been asked to call the attention of the meeting to some specimens on the walls, and would apologise for not doing so, because the indiscriminate introduction of inventions was perhaps not desirable. In the present instance the exhibitor was not merely the owner but also the producer of the invention. The inventor, who lived in London, was a man of some artistic ability, and the process, which was called xylography, was somewhat similar to that called xylatechnigraphy, described in a paper recently read before the Institute by Mr. G. T. Robinson. By means of the peculiar nature of the ink employed the inventor obtained a cheaper impression than had hitherto been produced in wood.

Professor Kerr, in rising to propose a vote of thanks to Mr. Smith, said that the subject selected was one upon which he thought it would be well if an annual paper were read. The public complained of the backwardness of architects in the introduction of new inventions, and he thought it would be good policy to meet such an objection in the mode suggested, as the difficulty he was convinced would not lie in finding material for discussion, but rather in confining the material within reasonable limits. The paper was very suggestive, and, like all that Mr. Smith undertook, was modest and unambitious: he knew where to stop. One thing, Professor Kerr said, he could not help observing—that although Mr. Smith began by saying, in effect, that building was making no progress at all as compared with the progress made in various other arts, yet in the course of his disquisition he proved that building was making very great progress indeed. This was sufficiently apparent to any one who looked back twenty or thirty years, and still more so to those whose memory could carry them back to a remoter period. Mr. Smith had referred to the use of iron and glass for structural purposes; and the extent to which those materials had developed in various departments was remarkable. At the same time, the crystal palaces built in various parts of the country, although works of great magnificence, could not, structurally speaking, be regarded as a great success. Great effects were no doubt accomplished, yet he did not think that architecture had, constructively speaking, very materially advanced by that invention. One matter well worthy of consideration was whether steam might not be rendered subservient to building processes. In his (Professor Kerr's) opinion the Vienna dome or Vienna cone) as it ought properly to be designated) was one of the most remarkable inventions of modern times—its marvellous simplicity was extremely interesting, and he would repeat what he had said before, that students of construction would be well repaid by mastering the principles involved in its construction. With regard to Phillips' girders he thought the invention was meritorious, and scarcely deserved to be passed over with the assertion that it consisted mainly in the accumulation of material at the neutral axis, because the simplicity of the girders, and the absence of riveting were most important features and worthy of careful study. As to the selenitic mortar, of which Mr. Smith spoke with much approval, it was rather a peculiar thing, and he believed that although General Scott was credited with its discovery, selenitic mortar was, in fact, based upon an invention of Mr. Westnacott—the only difference being that, for the purpose of expelling the carbonic acid from the stone, gypsum was substituted by General Scott for ground chalk. Upon the question of concrete he maintained that a concrete wall, as compared with stone or brick, was the only perfect wall we had; the only difficulties were in the successful manipulation of the concrete, and in making it air-tight. The wet might, he believed, be excluded from a concrete wall by the application of cement; and concrete should not be re-

garded as a substitute for brick and stone, but as something entirely distinct. Upon the interesting subject of artificial stone, the Professor said that he was glad to hear Mr. Smith touch. Ransome's artificial stone would probably have been much more extensively used if it had not been brought out at too high a price to admit of its competing with natural stone. The material was used extensively in America, but only to a very limited extent in England. The question of terra cotta had been dealt with very properly, but not exhaustively, by Mr. Smith. He (Prof. Kerr) thought that in designing terra cotta they should endeavor to accommodate it to the roughness of the materials with which it was associated, and he objected altogether to the principle of the indefinite of the reproduction of the same kind of forms.

Why should not terra cotta instead of being treated for the sake of obtaining an infinite reproduction of the same feature be handled with the tool in such a way as to procure much greater variety ?

THE MAGNETIC IRON ORES OF NEW JERSEY—THEIR GEOGRAPHICAL DISTRIBUTION AND GEOLOGICAL OCCURRENCE.

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Transactions of American Institute of Mining Engineers.

The magnetic iron ores of New Jersey are found in the northern part of the State, in the Highland Mountain range, which runs from the New York line on the northeast, to the Delaware River, near Easton, at the southwest. The same range continues across Orange County to the Hudson River, and towards the southwest it is known in Pennsylvania as the South Mountain. It is more properly an elevated table-land, quite deeply furrowed by several narrow, longitudinal valleys, and shorter cross-valleys or gaps. The ridges or lines of elevation, as well as the lower valleys, conform in their general direction very closely to the general trend of the whole belt or table-land, that is, from northeast to southwest. This also agrees with the prevailing strike of the rocks. This great uniformity in the altitudes of the hills and ridges, and the direction of the lines of depression corresponding to the strike of the strata, point to an original table-land, which, through the long action of denuding agents, has been quite deeply eroded, giving rise to the present surface configuration, so that some of the former and uniform features have been partially obliterated. The very few cross-valleys or depressions are much more irregular in their course, and serve as outlets through which the drainage is carried either into the Kittatinny Valley on the northwest, or to the broad, red shale and sandstone plane bounding the highlands on the southeast. The area of this highland region in New Jersey is about nine hundred square miles. Its average elevation above the ocean is about one thousand feet.

Except the valleys towards the northwestern border, as the Wallkill, Musconetcong, Pohatcong, and German, which contain magnesian limestone and Hudson River slate, this whole range consists of crystalline rocks, mainly gneiss, granite, syenite, and limestone, covered in many places by drift and alluvial beds. These rocks resemble closely those of the Laurentian formation of Canada, both in their structure and mineralogical characters. Stratification is nearly everywhere plain, indicating a sedimentary origin and subsequent metamorphism. In the Geological Survey reports of the State they have been described as belonging to the "Azoic Formation."

It is in this series of crystalline, metamorphic rocks, that the magnetic iron ores occur. The extent of this outcrop and the iron mines and localities at

which ore in workable amounts has been obtained, are both indicated upon the geological maps of the State survey, one of which has just been published. This map shows the mines as in lines nearly parallel to one another, and having the same direction as that of the whole belt or range. In some instances they are so close as almost to form a continuous line, as the Mount Hope, Allen, Baker, Richards, Mount Pleasant, and others, near Dover, in Morris county. Others appear in a sort of *en échelon* arrangement.

This occurrence in *lines*, or what may be more properly termed *ranges*, is so well known that miners and those searching for ore speak of veins continuing for miles, and of certain mines belonging to certain veins. Large and productive mines, as the Hibernia, Mount Hope, Dickerson, Ogden, and Kishpaugh, with others, give names to such lines. The complete breaks in veins worked, and the absence of any indications of continuity, show that these popular theories are not yet substantiated by the facts, although, if by the terms *lines* or *veins*, or, better, *ranges*, series of ore-beds whose several lines of strike or axes run closely parallel to one another, are meant, then they have a foundation in truth. In the "Geology of New Jersey," published in 1868, the mines then opened were grouped in such lines, and these were called ranges. The map accompanying that report, as well as the one just issued issued by the State Survey, shows these lines and the intervening belts. A comparison of these two maps confirms in some degree this theory of ranges, or what would be better termed, ore-belts, inasmuch as the hundred or more new mines and ore outcrops opened since 1868, and represented on the latter map, are nearly all either on old and well-known lines or what must be considered as new ones. These discoveries have shortened the gaps and widened the ranges. Thus the new mines near Chester, and those along the eastern base of Copperas Mountain, all in Morris County, have filled in wide blanks, and greatly extended what were but very faintly indicated as ranges or belts of ore. The numerous openings quite recently made on Marble, Scotts, and Jenny Jump Mountains, in Warren County, constitute a new and marked line. In this the manganiferous character of the ore throughout its whole length seems to give additional evidence in proof of such a relation. An order of arrangement or division into such lines or belts, based upon lithological and mineralogical characters, has not been possible, but it is hoped that further studies will develop the existence of such characteristic features which will confirm the indications from the geographical distribution.

The last map also shows *groups of mines*, between which very little ore has been found. One of the best known and largest of these groups is near Dover, Morris County, and a map of this district was published in 1868. Northeast of this there is an interval of several miles, extending almost to Ringwood, in which there are no working mines, and comparatively but few localities where ore is known to exist. But the newly opened Board, Ward, Green Pond, Pardee, and Splitrock mines, show that the lines of ore are beginning to be traced into this hitherto barren district, and point to future discoveries which will connect the Ringwood and Sterling groups with the Morris County lines. A lack of cheap and ready transportation has prevented the thorough examination of this part of the State, or the development of any localities which were promising.

The extended workings in the older mines are also doing much to prove the great length, and probably continuity, of some of these veins. Thus the long run from Mount Hope to the Dickerson mine, a distance of seven miles, has been so opened as to show an almost uninterrupted bed or vein of ore, or a series of veins parallel to each other, and all within a very narrow belt; and all of the facts of geographical distribution, as well as the arguments which could be drawn from the probable mode of origin of this ore, tend to support this theory of *lines* or *ranges*, or better, perhaps, *belts* of ore.

Magnetite, as a mineral, is very common in the crystalline rocks of the Highlands, occurring more frequently than any other mineral, excepting the ordinary constituents of the gneissic rocks, viz., quartz, feldspar, mica, and hornblende,

And so widely is it distributed that it is impossible to find many strata in succession where it is entirely wanting. It appears as one of the constituent minerals of these beds, either wholly or in part replacing their more common components, or it is added to these, and in each case occurs in thin layers or laminæ alternating with them, or it is irregularly distributed through the rock mass. The unstratified granitic and syenitic rocks, as well as the bedded gneisses, also often contain magnetite. In these, however, it occurs in larger and more irregular crystalline masses or bunches, and does not appear to be so properly a constituent of the whole, but rather as foreign to it. The same mode of replacement is sometimes seen in these as in the stratified rocks. In both these classes it enters into the composition in all proportions, increasing in amount until the whole is sufficiently rich to be considered as an ore of iron. Between rock entirely free from magnetite and the richest ore there is an endless gradation, making it impossible to fix any other line of demarcation between them other than that of the minimum percentage for the profitable extraction of the iron. Three modes of occurrence have been assigned to this mineral, two of which are in the rock, as one of its constituents either in irregular bunches or in a granular form, and the third in *seams* or *strata*, when it is called *ore.* But these distinctions are not fixed, and therefore it is better to consider it as one of the more common minerals of these gneissic and granite rocks, and in places forming the whole mass, or else so much of it as to be workable, and then to be called an ore. Rock containing from twenty to forty per cent. of metallic iron, the most of which is in the form of magnetite, has been found in many places, and some of these have been explored to a considerable extent in searching for richer ores. The granitic and syenitic rocks containing magnetite are generally found to cut the beds of gneiss, and are, geologically, huge ore-bearing dykes. The most common mineral aggregation is feldspar, quartz, magnetite, and hornblende, or mica, although in some cases both the latter enter into the composition. Such rock is worked at a few points, but these operations are not yet worthy of the designation of mines. And, in fact, the great irregularity and the varying percentage of iron in it does not make it a desirable ore. Gneiss containing magnetite in quantity sufficient to render it workable, has been opened and mined at several localities. Perhaps it should be called *lean ore.* One of the most extensive outcrops of such ore is near the Pequest mine, in what is known as the Henry tunnel, about two miles north of Oxford Furnace. Here there is a breadth of twelve feet or more, in which the beds are highly impregnated with magnetite, while those on each side are free from it. Extensive drifting and sinking have exposed several hundred feet of these beds on the line of strike, and shown an increase in the percentage of iron going from the surface to the lowest levels. Near Hackettstown, in Warren County, there are several localities of such *ore-bearing* rock, but nearly all of them are failures as mines. The Scrub Oak mine, near Dover, the Combs mine, near Walnut Grove, the Swedes and Beach Glenn mines, also in Morris County, have large portions of their *veins* so mixed with rock that they may be classed with the above localities of *ore-bearing* gneiss. And all the lean ores of the State may be considered as gradations in the series from rock to what is conventionally termed *ore.*

While it is impossible to separate these lean ores from the rock upon any decisive or marked distinctions or differences, the richer ores are to be considered as a distinct mode of occurrence, as these differ from the lean ores and rock in their simplicity of composition, being made up of fewer elements, and these predominating to the exclusion of all others.

Assuming this as another mode in which the magnetite occurs, the geological features of these *seams* or *strata* may claim our attention.

They are often called *veins* because of their highly inclined or almost vertical position, and hence resemblance to true veins. Their irregular form has helped to strengthen this opinion of them. But as they show well-marked planes of stratification and also lamination, both parallel to the beds of gneiss which inclose them on the sides, and have strike, dip, and pitch, and are folded, bent, con-

torted, and broken, just as stratified rock, they must be called beds, and be classed among the sedimentary rocks. The irregularities in their extent, thickness, and the presence of included masses of rock, known as horses, are phenomena common to the gneiss and them, and therefore these cannot serve as an argument for calling them veins. Lenticular masses of micaceo-hornblendic gneiss, lying in feldspathic and quartzose beds, or the converse, are quite common, nor do the strata of these rocks run on unchanged in character. But they thin out or grow thicker, or change in mineral composition just as these veins are seen to *pinch out* or swell into thick *shoots*, or be replaced more or less gradually by rock. The similarity in these respects between these ore masses and the surrounding stratified rocks proves them to be beds and of contemporaneous origin. Imbedded in the gneissic strata of this highland belt or region, these iron-ore beds or veins (so called) have the same general strike or dip in common with them. The prevailing direction of the first is towards the northeast, varying, however, within the quadrant from north to east. In most cases it is between the north and northeast. From these there are several exceptions, as at Oxford Furnace, where the veins run north 25° west; the Connet mine, a few miles west of Morristown, where it is also northwest and southeast. While these lines of strike have a general straight bearing, they exhibit short irregularities and deflections, often varying from side to side, or zigzagged by faults or offsets. The rocks of this formation, as observed in hundreds of places, show the same prevailing straight lines as are seen in the longer openings for ore. Bends or foldings are very rare. One of the most remarkable of these is on Mine Hill, Franklin, Sussex County, although this occurs in a zinc vein or bed, and not in iron ore. Here there is a quite sudden bend, so that the vein returns almost to its original course—which is the usual northeast and southwest one. In the iron mines of the State, the Waterloo or Brookfield mine, about five miles north of Hackettstown, in Warren County, shows a curving strike—turning from northeast and southwest to north and south. Further opening may find as complete a bend here as is to be seen on Mine Hill. But the best example of such folding is at Durham, Pa., where the iron-ore vein, as followed in the mining operations, coincides in its course very nearly with the contour line of the Mine Hill, running around in a semicircle on the western side of this elevation.

The dip of these ore-beds being at right angles to the line of strike has, of course, the same degree of uniformity in direction, and that is towards the southeast; or more generally towards the east-southeast. In some localities the strata are in a vertical position or inclined towards the northwest, and the dip is in that direction. But this has been observed in a few mines only, and in some of these, deeper working has found the vein below assuming the prevailing southeast dip, indicating the existence of a fold, of which the *vein* opened is a segment, or a bending over near the surface caused by some powerful force acting subsequently to the elevating and folding agents. The Beach Glenn and Davenports' mines, in Morris County, offer illustrations of northwest dips. The rock outcrops show a number of such directions, but they are comparatively few in number, when the thousand or more observed southeast dips are considered. In the Connet mine (mentioned above) the dip is towards the southwest. At Durham it is radiating towards a central axial line of what is considered as a fold, and in, towards the centre of the hill. In the Hurd mine, as also at the zinc mine, Franklin, the two legs of the synclinals show dips at different angles towards the southeast, one of those at Hurdtown, being almost vertical, while the other is quite steep. In the large openings of the Ford and Scofield mines there is no dip, the beds standing vertical.

The term *pitch* is used to designate the descent or inclination of the ore-bed or *shoots* of ore towards the northeast—or in the line of strike. If we should conceive of the line of strike as broken and depressed so as to descend towards the northeast, we should get a good example of this *pitch* of *shoots*. This inclination has been observed in the rock as well as in the ore. It is so commonly observed in mining these magnetic ores as to be expected everywhere, and min-

ers speak of the ore *pitching* or *shooting*, and their working has constant reference to such a structure in both ore and the inclosing rocks. In nearly all cases the pitch is towards the northeast. It is beautifully exhibited in the Cannon mine, at Ringwood, where it amounts to 45° inclination from a horizontal line. The long slope of the Hurd mine, in Morris County, and the thick swells alternating with intervening *pinches*, or barren ground, at Mount Hope, show this same structural phenomenon.

These *shoots* of ore, however named, are best described as "irregular, lenticular masses of ore imbedded in the gneiss, their longest diameters coinciding with the strike and pitch of the rock," which in nearly all cases is towards the northeast, and their dip conforming to that of the same surrounding rocky *case*, and generally at a high angle towards the southeast. They vary greatly in their dimensions, sometimes thinning out or *pinching*, when followed on the line of the strike, or on that of the dip, to a thin sheet or seam of ore and occasionally ending wedge-like in rock. Sometimes they split up into several small veins or *fingers* which are dovetailed, as it were, in with the rock, and so gradually pinch out. Quite often there is a sort of flattened kernel or core of rock inclosed in the shoots of ore, but generally these *horses*, or what are called such, are interpenetrating masses of rock from the outside *country rock*. Extensive mining operations and explorations have shown some of these shoots to be connected with others, forming a series of these lenticular masses, or if not actually united by ore, associated and arranged on closely parallel planes, if not in the same axial plane. Following the plane of the dip downwards, the *pinches* between the shoots are nearly everywhere continuous sheets of ore, and these are not often greater in breadth than the shoots. That is, the distance from shoot to shoot measured across the pinch is not often greater than the breadth of the former. But quite frequently these shoots are entirely separate from one another, rock intervening in the same plane, or they are in different planes or geological horizons. Nearly all of our New Jersey mines work on more than one shoot, since the extraction of the ore from near the surface is easier and more economical than following a single shoot downwards. Their length is unknown. In the Hurd mine the slope is nearly 900 feet long descending on the *bottom rock* and there are no signs of exhaustion. In the Weldon mine (near the Hurd mine) there are two shoots side by side, but not exactly parallel, nearing each other as they pitch down, and now separated by about twelve feet of gneiss rock. These may come together and prove to be leaders from one large shoot.

In most of our iron mines the ore is bounded by well defined walls or strata of rock from which the ore comes off *clean* in mining, but very frequently there are no such plain boundaries or sudden transitions from magnetite to gneiss, but a very gentle gradation of ore into rock, and in these cases the mining goes only so far as the richness of the beds in iron makes it profitable to remove them. Following the *shoots* downward, the same gradual replacement has been observed until the whole was too lean to work, or altogether free from ore ; but this feature is not so common as that of the gradation or replacement towards the sides of the shoots or the walls. Occasionally the shoot is said to run out, that is, there is a sudden change from ore to rock ; some of these, however, may be faults rather than shoots changed in mineral composition.

The thinning out of the shoots towards the edges, or at right angles to the line of pitch, or towards what may be called the *lines of pinch*, which run parallel to the lines of *swell* or axes of these shoots, has originated the terms cap-rock and bottom rock. The former makes the arched or double-pitched roof of the mine, while the latter constitutes the trough-like floor or bottom. These peculiar features are very finely exhibited in the Hurd mine, Hurdtown, Morris County, where the extraction of the ore, following the conformation of the shoot, has left the *cap-rock* overhead and the *bottom rock* below, on which the long slope runs down to the bottom of the mine.

In the Cannon mine, at Ringwood, the same capping rock appears in the heading or northeast side of the large opening, and the track runs down on the bottom rock towards the northeast.

Here the pitch is nearly twice as great as in the Hurd mine and the shoot as worked is much broader being nearly of the same size both ways. And here there may be said to be *four* walls that surround the ore. Sometimes miners speak of these top and bottom rocks as walls. But generally there is a narrow vein or sheet of ore left both at the top and in the bottom; and these may gradually run out entirely, or they may connect with other shoots of ore lying in the same plane of dip as that of the shoot worked. And this is true in nearly every case; the exceptions being considered as not yet fully demonstrated as such, since the mining operations generally cease when the vein pinches up so as to become unprofitable for the removal of its ore.

The extent of these *shoots* of ore is exceedingly varying, and our mines are not yet deep enough to show their maximum length. The width and thickness, or the lateral dimensions, are soon ascertained, the former scarcely ever exceeding one hundred feet, from *cap* to *bottom rock*, or from *pinch* to *pinch*; and the latter varying from an inch to eighty feet; but more often less than thirty feet—they may average five to twenty feet. These figures always include some rock, or *horses*. The oldest and deepest of our mines, as the Blue mine, at Ringwood, the Mount Hope, Swedes, Dickerson, and Hurd mines, are all steadily going down, increasing the length of their slopes, and they are apparently as inexhaustible as ever, and promise to continue so, at least as far as our present appliances for hoisting ore and water can allow of the economical extraction of ore from them. Such are some of the more general and essential features that characterize the iron-ore beds of the State.

Lying imbedded in, and being contemporaneous in origin with, the gneissoid rocks of this Azoic formation, these ore beds or *veins* have been subject to the same disturbing forces which have elevated, folded, wrinkled, and broken all the strata belonging to it, and which have given to it its present structure. These forces, so manifold and acting through so long a period of time, and probably at wide intervals, have so destroyed any degree of uniformity which once may have existed, that it is often difficult, and sometimes impossible, to recognize amidst this chaos any order of structure whatever. The beds of ore and rock have been squeezed into close folds, so that they now stand on edge, and through these agencies have come the strike and dip. Other forces acting on lines traversing the veins at all angles, have variously dislocated and further disturbed the strata, giving rise to frequent *faults* or *offsets*, and what are called *cross-slides*—phenomena seen in both the veins and in the rock strata of this formation. In some instances the veins have been displaced one hundred feet, while in others the ore-mass has been broken apart, but not pushed aside, so as to interrupt its course. The planes of these dislocations traversing the veins in all directions, the dip and strike are sometimes both altered. These faults are common, and can be seen in nearly all of the mines; sometimes so frequent as to cut the vein into short segments, giving it a zigzag course. The most remarkable faults or offsets are seen in the Mount Hope mines, where five veins are all displaced over a hundred feet; in the Hurd mine, where the displacement has been in a vertical plane and the original long and continuous shoot appears as two distinct masses, the upper of which has been worked out. Other examples are in the Byram and the Mount Pleasant mines, near Dover. Generally a thin seam of ore mixed with rock connects the vein on corresponding sides of the fault, and this serves often as a guide to find the vein beyond the break or offset. Miners have several so-called rules about offsets, but these are not universal, and there is no general law in the direction of the throw or displacement. Occasionally one fault is crossed by another—increasing the irregularity in the course of the vein.

From these numerous faultings, discovered in mining operations, we learn something of the extent to which these strata have been disturbed since their original deposition, and probably all subsequent to their elevation and compression into folds. More thorough surveys of the surface and more extended mining may yet enable the geologist and miner to trace out these lines of fracture, and learn how much they, together

with the general effects of elevation and folding of the whole formation, have contributed towards the grouping of the iron-ore as we find it, and this knowledge may direct both our mining and our searches for ore. The facts already obtained point to a system, and the successful pursuit of the ore in its crooked and broken course in some of the largest mines is the best evidence of the accuracy of the laws of structure as now understood.

They also show most forcibly, and illustrate most beautifully, the intimate and necessary relations of mining and the principles of geology, and show that the two ought never to be dissociated.

VENTILATION BY VERTICAL SHAFTS.

From "The Architect."

The *Times* has published a long article upon a discovery by a Mr. Tobin, of Leeds, of a method of ventilation which, it is affirmed, renders the atmosphere of any chamber as pure as that outside the building, without improper lowering of temperature, and without the production of draught. Mr. Tobin's own account of the matter is that he was once watching a current of water which flowed into a still pond. He observed that the moving water kept together, and held its own, until its course was arrested by the opposite bank, when it curved gently round on either side, and was lost insensibly in the general body, which had its outlet for overflow at one side. He reflected that a current of air introduced into a room would act precisely in the same manner, keeping together until it encountered an obstacle, then mixing insensibly with the air around it, and compelling an overflow wherever there was an opening available. He saw that, if this were so, it would only be necessary to give the entering current an ascending direction, so that it would reach the ceiling without impinging on any person, in order to solve the whole problem of domestic ventilation. Experiments at his own house confirmed his anticipation, and led him to contrive methods, which he has patented, of carrying his principle into practice.

At that time the state of the Borough Police Court at Leeds was, as, indeed, it had been for some time previously, a source of great perplexity to the Town Council. The Justices were often compelled to make their escape before the business of the day was concluded; and the Council had expended between £1,400 and £1,500 on successive ventilation doctors, each of whom had left matters as bad as, if not worse than, they were before.

Mr. Tobin suggested that the Council should pay him a nominal royalty for the use of his patent, and that they should pay the few pounds required for doing the work, leaving his own remuneration to their discretion when they saw the effect. These terms having been accepted, he placed under the floor of the Court three horizontal shafts which communicated with the open air through a cellar grating. From these were brought eight vertical shafts through the floor at different points. The shafts rise about four feet above the floor, and are each five inches in diameter. They have open mouths, and are placed out of the way in corners, or against the partitions of the Court. From each shaft there ascends to the ceiling an unbroken current of the outer air, like a fountain, or like a column of smoke when the barometer is high. The current will support feathers, or wool, and other light substances, and has so little tendency to spread laterally that it can be made to influence half the flame of a candle, while the other half remains undisturbed. A person resting his cheek against the margin of one of the tubes feels no draught, and the hand feels none until it is inclined over the orifice. The effect was instantly to render the Court as fresh and sweet as the external air of the building, as the products of respiration was forced out through the skylight.

After three months' trial, and after all

the magistrates for the borough had joined in a report, which expressed their entire and unmixed satisfaction, the Corporation voted Mr. Tobin an honorarium of £250, to express their sense of the benefit which he had conferred upon the town. They also applied his system to the Council Chamber; and their example was followed by some of the leading bankers and merchants, by the churchwardens of St. George's Church, and by the proprietors of the *Leeds Mercury*.

The system of vertical tubes is necessary for rooms which have no side windows, or which have only a small window surface in proportion to their cubic contents. But Mr. Tobin at the same time contrived a cheap and simple method, by which vertically ascending air currents can be introduced through common window sashes; and this method will suffice for all ordinary living or sleeping apartments. Each of the openings made for this purpose is provided with a cover by which it can be closed at will; and they admit of a method of securing the sashes which affords almost entire security against burglars. A very competent authority has communicated to the *Times* his experience for eight weeks of a room containing 2,500 cubic feet, ventilated, under Mr. Tobin's direction, by four window openings which have an aggregate area of 30 square inches, but which are filled by layers of cotton wool to filter the entering air from dirt and moisture. The currents ascend in absolute contact with the glass, keeping so close to it that they do not not affect the flame of a taper which is held vertically in contact with the sash bar; although, as soon as the taper is inclined towards the pane its flame is strongly fluttered. In this way the air ascends to the top of the window, where it is directed to the ceiling and lost as a current, being no longer traceable by taper, hand, or fragments of down, although closing the window openings diminishes in a marked manner the draught up the chimney. Each opening, as already described, has an independent cover, and, without the wool, the four would, in cold weather, be too much for a room of the size specified. With the wool they do not perceptibly diminish the temperature, but they give a feeling of absolute out-of-door freshness, which must be experienced in order to be appreciated. There is no draught anywhere, and the openings are not visible unless sought for, so that curious inquirers who have remarked on the result have been unable to find the inlets. Arranged as described, the openings are sufficient to feed a large argand table gas burner, and to sweep away entirely the products of its combustion; so that, when the room is shut up, with the gas lighted and with a good fire, for three or four hours, persons entering it from the open air are not able to discover, except by the greater warmth, any change of atmosphere. A bed-room ventilated in a similar manner is as fresh when the door is opened in the morning as when it was closed at night.

Mr. Tobin's experiments early led him to the conclusion that the prevailing notions about the necessity for carefully planned outlets were fallacious, and that, if proper inlets are provided, the outlets may generally be left to take care of themselves. In order to test this, he fitted two vertical tubes into a small room which had a fire-place and a three-light gas pendant. He closed the opening of the fire-place, and every other opening into the room, except the tubes, hermetically, and shutting himself within, pasted slips of paper all round the door. He found that there was then no entrance current by the tubes. The room had no outlet; it was full of air, which his respiration had not had time to consume in any appreciable quantity, and no more could get in. He next lighted the three gas burners, and a steady entrance current immediately set in through the tubes, and continued as long as the gas was burning. He waited nearly an hour without any deterioration of the atmosphere becoming perceptible to his senses, and with the currents steadily coming in and ascending in their customary manner. He then cut through the paper which secured the door, and left the room, shutting the door behind him. Returning half an hour later, he found the atmosphere still fresh. He next extinguished the gas, and the currents gradually died away, the original state of equilibrium or fulness being restored. This experiment, which has been several times repeated, seems to show that the external air will enter just in proportion as room is made for it by

combustion or respiration, and that the rate of supply is essentially governed by the rate of destruction or demand.

In order to obtain an absolutely perfect result it is necessary to bear in mind that the behavior of the entering current will be precisely like that of the vertical column of water sent up by a fountain, except that, as the ascending air is received in a fluid of only little less density than its own, it will mingle with that fluid gradually when the propulsive force is exhausted, instead of falling almost vertically by the action of gravity. But just as a fountain, if it encountered an obstacle while its column was still compact, would rebound from that obstacle with considerable violence, so the entering current of air, if it meet with an impediment prematurely, will be reflected as a draught. To prevent such an occurrence, it is necesssary to make the inlets so low down that, under all ordinary circumstances, the force of the stream will be expended before the ceiling is reached; and when, from any circumstances, this cannot be done, the current may be broken by strainers of wire gauze or other suitable material. In this, as in most other matters, some special adaptation of means to ends is required; and the arrangements for any given room must be planned by some one who has practical knowledge of the subject.

Within the last two or three weeks Mr. Tobin has adapted his system to the Liverpool Police Court, and there, as well as at Leeds, he has entirely succeeded in attaining his object, and the satisfaction given to the local authorities has been such that it has been determined that all the other courts in the Town-hall shall at once be ventilated in a similar manner. In London the method of ventilation by vertical tubes has been applied to one of the wards of St. George's Hospital, and that by window openings to the Council Chamber of the Society of Arts and to a few private houses, everywhere with the same excellent results.

The discovery that the pressure of the atmosphere can thus be utilized as a perpetual source of air supply, without the aid of fans or other mechanical contrivances; the discovery that all draughts can be obviated by the employment of vertical entrance channels, provided only that their mouths are not too near the ceiling, and the discovery that improper lowering of temperature is prevented by the circumstance that the rate of entrance of air is governed by the demand, are truly comparable in their simplicity to the balancing of the egg by Columbus. Simple as they are, they are none the less calculated to add greatly to the public health and comfort.

Captain Douglas Galton, commenting on the invention, says:—The principle of ventilation by utilizing the pressure of the atmosphere is not new. It has been applied in a number of ways in various public and private buildings; notably in the method of barrack ventilation adopted in 1857 by the Barrack and Hospital Commission under Lord Herbert's auspices. Nor is there any novelty in the method of introducing fresh air into a room by means of vertical shafts delivering the air into the room at a few feet from the ground. I used it in 1861 in the wards of the Herbert Hospital at Woolwich, and in other hospitals, but I utilized the fire-place for the purpose, placing it in the centre of the ward, with its flue carried under the floor, in order that in cold weather the fresh air should be tempered by the spare heat from the fire. Plenty of other instances might be cited.

The principles of ventilation are well known. It is the application of those principles in special cases which causes the difficulty. The amount of current of inflowing air into a room will depend upon the facilities or arrangements for outflow, and *vice versa*. Therefore, for perfect ventilation, the proportions and position of both outlet and inlet must be considered; neither can be neglected; and if in the room on which Mr. Tobin experimented the air remained pure, it was because there was, in addition to the inflow, some means for an outflow of a sufficient quantity of air to remove the impurities given out from the lungs in breathing and from the gas in combustion. In English rooms of ordinary construction the open fireplace creates the difficulty in the introduction of fresh air. It is the cause of draughts, because the chimney with a fire in the grate is a strong engine for removing the air from a room, and it draws in through every

means of ingress air to supply the place of that removed. If this air comes in cold draughts are felt, whatever be the position or manner in which the air is delivered. The hotter the fire the stronger the current up the chimney, and the greater the draught. For this reason, if a room with an open fire is to be really comfortable it should be provided with a continuous supply of fresh warmed air, and if the inlet be from 6 to 9 feet above the floor the inflow will not be felt by the occupants. The waste heat from the fire affords the most economical method of warming the fresh air.

When the principles of ventilation, which are perfecly well known, are carefully attended to, and where the inlets for fresh air and the outlets are duly proportioned to each other and placed in proper positions, and the fresh air adequately warmed and cooled as required, there will be no failure in ventilation. Where failure does occur it is either because of a misapplication of principles, or of a disinclination to incur the necessary expense for carrying the principles into effect.

THE STABILITY OF ARCHES.

By E. SHERMAN GOULD, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

It is customary, in discussing the conditions of stability of an arch, to consider the arch-ring as sustaining, besides its own weight, that of the entire superstructure raised over it, and receiving at the key-stone the whole horizontal thrust of the combined mass.

That this view is an erroneous one, is clearly evidenced by the perfect stability of many light arches standing under high spandril walls ; a stability which could never exist were the actual conditions of pressure such as would be commonly assumed in calculating the proper dimensions for the arch-ring.

Such a pressure from the surcharge is only found in the case of a liquid mass, and then the direction of the pressure upon each voussoir is toward the centre of the arch, and not vertically downward as in the case of a coherent mass, bonded in with the extrados of the arch-ring.

Suppose, in the case of a spandril wall, such as is shown in half elevation in Fig. 1, that the arch-ring were removed. What would be the result? If the common assumption were true, the entire wall within the span, would fall bodily to the ground. Now we know that this would not really occur, but that an irregular mass A, varying in size according to the span and character of the wall, would detach itself and come down, not probably in a body, but by piecemeal.

In general terms, we may say that the office of the arch-ring is to sustain that

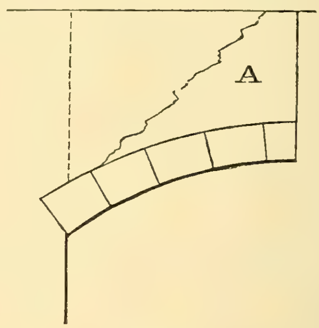


FIG. 1.

portion of the surcharge which is not self supporting. Moreover, the arch and wall thus sustained, form together an arched girder, and the horizontal thrust of the combined mass is resisted by the entire section from the soffit to the top of the wall. So that, in point of fact the higher the wall the greater the safety to the arch-ring. Indeed, one would feel instinctively, that he could knock a hole through the foot of a high brick wall with greater impunity than through a low one, particularly if there were a heavy surcharge resting on the top.

In this connection I may be pardoned for offering what I consider a much sim-

plified method of determining the line of pressure in an arch-ring. The plan, introduced by Mons. Méry, and I believe at present almost universally adapted, at least in principle, is to ascertain the weight of arch including surcharge, ascertain its centre of gravity, derive the horizontal thrust, apply this latter to some point in the vertical section of the crown, and, combining it with the weight of successive portions of the arch, work the resultant down to skew-back. The consideration of certain facts in relation to a loaded arch lead us, I think, to a preferable method of procedure. Whatever may be the conditions of loading, and whatever direction the line of pressure may consequently follow, we know that each abutment must sustain one-half of the weight of the arch and load, and that this weight on the abutment must have a resultant at right angles to the skew-back. We have then here a positive basis to start from, and by combining this resultant with the weights of the successive voussoirs and their respective loads, we can trace the path of the line of pressure through the arch-ring.

Thus, suppose Fig. 2 to represent an arch, 60 feet in span, with a rise of 15

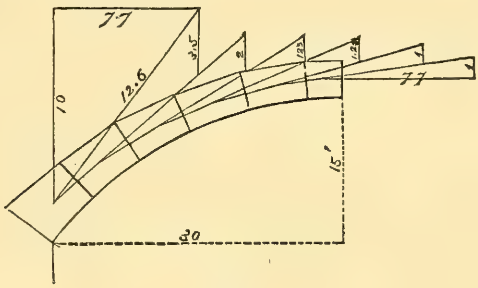


FIG. 2.

feet, the intrados being the arc of a circle, struck with a radius of 37.5 feet. Let us suppose the weight of voussoirs and corresponding loads, commencing next to the skew-back, to be represented by the numbers 3.5; 2; 1.25; 1.25; 1 and 1 respectively. This gives a weight, represented by 10, resting on the abutment. The reaction of this weight, acting vertically upward, and the horizontal thrust, have a resultant, as we have seen, named to the skew-back, represented by 12.6, the horizontal thrust being represented by 7.7. Transferring this triangle of forces to the centre of gravity of the first voussoir, and combining the weights in and on each voussoir successively, we carry the line of pressure through the arch-ring, and recover the horizontal thrust of 7.7 in the resultant at the crown. (This procedure will somewhat remind the railroad engineer of the method of locating a curve by chord deflections.) The shorter the voussoirs, the nearer the differential will approach to the arcs, the nearer the broken line will approach to a true curve, and the nearer will the first centre of gravity approach to the skew-back, and the last to the mid section of the crown.

This process demonstrates itself, and is moreover merely an application of the well-known principle of the suspended chain, but it will be satisfactory to apply it to some known curve of equilibrium, and see how they agree. Of all external pressures which we encounter in construction, hydrostatic pressure is the one about the action and direction of which we are most certain, and therefore, of all curves of equilibrium, the hydrostatic curve is the least ambiguous. Let us take the example of this curve, given by Professor Allan, page 387 of the tenth volume of this Magazine. With a span of 50 feet and a depth of load at the crown of 16 feet, the Professor gives as the radii, at crown and springing, of 32.5 feet and 14.1 feet respectively. He also gives as the formula $S=\frac{y_0 p_0}{y}$ for the radius at any point, situated at a depth y below the water line. The curve is now to be found by approximation. Start at the crown with the radius 32.5 and strike a short arc. From the end

away from the crown, measure the vertical distance y to the water line, and dividing the constant $y_0 p_0 = 5.20$ by this distance you obtain the next radius. Proceed thus to the end of the arch, when you will find that you have overrun the span by a distance less or more, according as the divisions have been more or less numerous. Now, begin at the springing, with the radius 14.1 feet, and work back toward the crown. You will find this new curve gradually approach the first one for a certain distance, and then begin to leave it. Stop here. You have now two curves, between which the true curve lies, and with one of which it coincides at the crown and springing. The margin will be less, the greater the number of small arcs you have taken. Sketch the true curve in by hand, and selecting, by trial, a few centres, strike in a clean curve coinciding with the hand-made one. It will be well to test these centres, and the corresponding radii, by the formula $p = y_0 p_0$, measuring p and y on the drawing. Now (Fig. 3), take the area a, b, c, d, say in square feet, which will

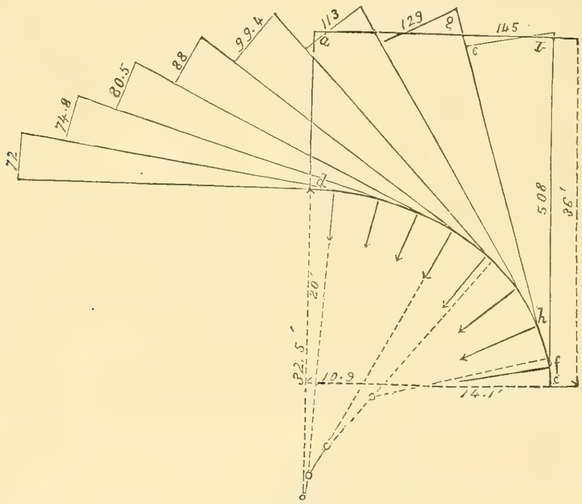


Fig. 3.

represent the weight resting on each abutment for a foot's length of arch. We have for this, the number 508. Then divide the curve into a certain number of equal parts, 8 in the figure, and multiply their common length by the distance from their centres of gravity to the water line. This gives the pressure on each of the equal arcs in terms of the weight on abutment, which pressure is directed toward the centre of the circle of the same radius as the arc. Draw lines from the centre of the arcs, properly directed, and make them of a length representing by scale the amount of pressure on the arcs to which they belong. Then, from the first centre of gravity, next the springing, draw the vertical 508, and from its upper extremity draw a line, parallel to the direction of the pressure on that centre of gravity, and equal, by scale, to its amount. This gives us the triangle of forces, b, e, f. Produce f, e, making h, g, equal to f, e, and proceed thus through to the crown. It will be found that the curve thus obtained coincides with the hydrostatic curve located by the formula, and the resultants equal T=H=V, as they should.

No account has been here taken of the weight of the voussoirs, which, as they act vertically, would somewhat modify the curve

In closing, I may add that I do not recollect seeing in any work in English, Dejardin's excellent and simple method of tracing the extrados of an arch in equilibrium, when the intrados is given. It is shown, in its most simple applica-

tion in Fig. 4, which represents part of an arch with arc intrados following a

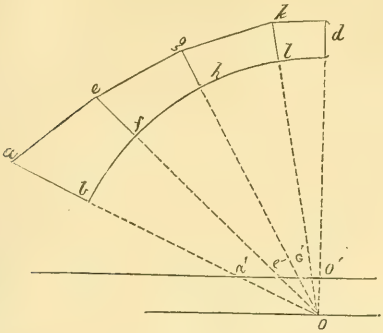


FIG. 4.

circular arc. The method is based on the principle, that, as the horizontal thrust is constant throughout the arch, the vertical projection of each joint $a\,b$, $e\,f$, etc., should be equal to the depth d, at the crown. This is secured by drawing a horizontal line at a distance $0\,0'=d$ above the centre of the circle to which the intrados is struck, and making the distances $a\,a'$, $e\,e'$, etc, on the radii produced, = radius.

This method is general. In the case of an intrados struck from several centres (Fig. 5), let

r = radius at the crown.

r' = radius at any joint, making an angle d with the vertical.

e = depth of arch-ring at crown.

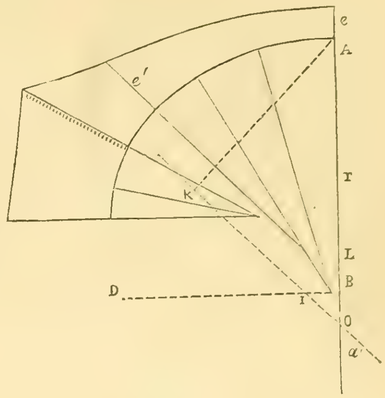


FIG. 5.

Then, $e'=\frac{r}{r'}\times\frac{e}{\text{Cos. } d}$, sufficiently near in practice.

On the vertical $O\,A=r$, take $O\,B=e$, and draw the horizontal line B D. To obtain the length e' of a joint making an angle d with the vertical, through O, draw O K parallel to the joint e', and $=r'$. Through the point I, where O K meets B D, draw I L parallel to A K. Then O L will be the length e' required. For, A O K, L O I being similar tringles,

$$O\,L=\frac{O\,A\times O\,I}{O\,K}=\frac{r}{r'}\times\frac{e}{\text{Cos. } d}.$$

TESTS OF STEEL.*

BY A. L. HOLLEY, C. E.

THE intention of this paper is not to discuss this important subject in all its bearings, but merely to point out why mechanical tests of steel, as ordinarily made, are not, *alone*, of any special value to engineers—certainly not to general mechanical engineers.

The agents of the Barrow Hæmatite Steel Company, one of the largest and most successful Bessemer establishments in England, have recently distributed a report, made by Sir William Fairbairn, on the transverse, tensile and compressive resistances of certain bars of this steel. The number of tests is very large; they seem to be careful and minute; and the modulus of elasticity, the work up to the limit of elasticity, and the limit of working strength, are fully tabulated according to the latest formula.

This is very well—indeed it is indispensable, as far as it goes; but it goes no further than to inform the ordinary engineer that there is an unknown substance which possesses these physical properties. As to *what* the substance is, the report gives him no working knowledge, for not a single analysis is given of any of the bars tested. The most

* A paper read before the American Institute of Mining Engineers.

that is said of some of them is that they are either "hard" or "soft," which is sufficiently evident from the experiments. "A bar of steel" is, in the present state of the art, a vastly less definite expression than "a piece of chalk." To the engineer who wants steel for a specific purpose, it gives only the faintest clue, to say that steel is hard or soft. There are a dozen grades of both hard and soft steel, adapted to different purposes. Rail steel is soft, and boiler-plate steel is soft, as compared with many structural steels, and with the whole range of spring and tool steels; but the one perfectly adapted to rails would be useless for boilers.

In order that engineers may know what to specify, and that manufacturers may know not only what to make, but how to compound and temper it, the leading ingredients of each grade of steel must be known. Pure iron would be unfit for nearly all structural purposes. Upon the substances associated with it depend its hardness, malleability, stiffness, toughness, elasticity, tempering qualities, and adaptations to various structural uses. These ingredients are indeed impurities, but the *term* "impurity" unfortunately implies a defect, whereas the *thing* may really impart the essential quality. All the usual ingredients give what is called "body" to steel. Carbon, within specific limits, as is well known, gives hardness, elasticity, resistance to statical strains, and tempering qualities. Under certain conditions of composition it even gives resistance to sudden strains. Manganese (and this fact, by the way, is not so generally known) gives, in the proportion of $\frac{3}{4}$ to 1 per cent., hardness, toughness, malleability, and elasticity. Chromium imparts similar qualities, but to what precise extent we do not know, in default of a proper comparison of chemical and mechanical tests. Silicon, although considered a bane by steel-makers generally, and, singularly enough, advertised as the great panacea for the weaknesses of steel by certain modern inventors, has probably, in proper proportions, a healthful influence on the physical properties of steel. Even phosphorus, the arch-enemy of the Bessemer and open-hearth manufacturers, may in some degree be a valuable ingredient.

Whether or not certain foreign substances, which separately added, produce similar results, would produce a better result if combined in certain proportions—for instance, whether carbon alone in any degree, or silicon alone in any degree, would make as good a steel for certain uses as carbon and silicon combined, it is, in default of proper experiments, impossible to state. The probability is, that there is a proportion of carbon and manganese which would give the highest possible value to all structural steels. We formerly added spiegeleisen to decarburized Bessemer metal solely to impart manganese to the oxygen of the oxyde of iron formed in the Bessemer process. We now add a larger proportion of spiegeleisen, not only to remove the oxygen, but also to mix manganese with the steel. And we think we find that if the proportions of silicon and phosphorus are sufficiently low, and carbon does not exceed a third of one per cent., manganese to the amount of three-quarters per cent. to one per cent. gives the resulting product a high degree of toughness and hardness combined—a degree of suitableness for rails, which no proportion of either carbon or manganese, not associated, can impart.

When we consider that two and three-tenths of one per cent., and in some cases a fraction of a tenth of one per cent. of foreign metals, will change the character of steel in a high degree; and when we farther consider that the physical results of these combinations have never been tested or analyzed in any thorough and comprehensive manner, we may well reiterate the common expression, that the iron and steel manufacture is in its infancy.

But it is not necessarily in its infancy. We simply do not develop it. The general complaint of engineers and machinists is, that they occasionally get, but can never get regularly, the precise quality of steel they require; and yet it is probable that thousands of tons of steel have been made which are suitable for each of these purposes, but have been used for others, and that the precise grade required in every case could be reproduced by the ten thousand tons. The trouble is that neither the user nor the maker knows what the material *is*.

They have put no mark on it by which they can recognize it; they have kept no recipe. All they can do is to use ingredients of the same name, and approximately the same quality, and to guess at the physical properties of the product, aided by such crude tests as can be made during manufacture. Mr. William H. Barlow, in a late address on modern steel before the British Association, says that one reason why steel is not more used for structural purposes is, that the metal is of various qualities, "and we do not possess the means, without elaborate testing, of knowing whether the article presented to us is of the required quality." But neither Mr. Barlow, nor any of his associates in government experiments, proposes the true solution of the difficulty. It is no more necessary to test one or two of each lot of bars to destruction, in order to find out the quality of the rest, than it is to burn up a Chinese village to get roast pig.

If the user would *analyze* not one, but twenty samples of the steel that meets a particular want, and then base his order on an analysis that should come within the highest and lowest limits of the samples, he would get substantially the same metal every time. The problem is a more difficult one for the steel-maker, since he must analyze the many materials that go into his product ; but if he imposes the same restrictions on the makers of these materials—in short, if from the ore and limestone and coal, up to the finished bar, each user buys by analysis, and pays in proportion to uniformity, the production of steel of the most multiform grades and qualities, each homogeneous and uniform to any extent of production, becomes a possible, if not a comparatively easy, matter.

What are Sir William Fairbairn, and Mr. Barlow, and Mr. Kirkaldy, and the other great experimenters in the physical properties of steel—in its adaptation to certain specific uses—what are they doing to relieve the engineering world from these uncertainties ? They are simply discovering the vast number of qualities which steel may be made to possess, without giving more than a clue to the method by which these qualities may be predetermined and reproduced. They are going to a vast expense of time and material to inform us, not that a certain combination of metals, but that a *bar of steel*, has such resistance and elasticity. This sort of experimenting has much the same value as the steam-engine tests of a late chief engineer in the navy, of whom it is said, that in a coal-consumption test he would calculate the ashes to ten places of decimals, and guess at the coal put into the furnaces.

Moreover, Sir William Fairbairn may be doing injustice to other steel-makers, to Brown, Cammell, and Bessemer, bars of whose steel he has also similarly tested, and found not quite so suitable for certain purposes as the Barrow bars are. But he neglects to make it clear that the disparaged bars may be better than these particular Barrow bars for other purposes. He makes the mistake which we should suppose Sir William, of all men, would not make, of being absurdly general and random in one element of his conclusions, while he is fractionally accurate in others—of cramming the whole matter of chemical ingredients into the terms "hard" and "soft."

The first and easiest step in the desired direction is to find out what X is. It is not necessarily a bar of steel made by Turton & Sons, which one tool-maker will swear by, and another will swear at; nor is it necessarily a boiler-plate steel which Park Bros. made once, and Firth got at twice, and Singer, Nimick, & Co. hit two or three times. It is a steel which Turton, and Firth, and Park, and Singer, can, either of them, make by the ten thousand tons, if you will only tell them what it is made of, as well as what its physical qualities are. In the various uses to which engineers have applied steel, there are a vast number of specimens which have long fulfilled all the requirements. When more steel of the same sort is wanted, the usual method is either to apply to the same maker, who kept no complete record, and does not know what is wanted; or to get bids based on a stereotyped and very inadequate physical test, for instance, that the bar must stand such and such a blow from a drop. The lot of steel is made, and is, as well it may be, very heterogeneous in physical character, although it may be in accordance with the one test. The result is that, under wear, some of it fails, or, under load, an excessive margin

of safety must be allowed. The obviously rational way to reproduce a lot of steel which is proved suitable for any purpose, is to analyze many samples of it—at least for carbon, manganese, silicon, phosphorus, and any element which exceeds a tenth of one per cent., and thus to give the steel-maker a recipe for making it.

It may be suggested that this chemical synthesis of steel will be ruinously costly. For certain exact purposes, such as the members of a long-span bridge; or for certain fine purposes, such as gun-barrels, the cost of analyses, or any loss in applying to other uses the lots of steel that were not up to the mark, would be very small compared with the extraordinary margin of strength that must be given to an uncertain metal, and compared with the cost of occasional failures under final test. And this cost, whatever it is, the user—that is to say, the public, snould and must bear.

But steel-makers will find that working by analysis is not so very formidable after all. The color-test of carbon is already applied to all charges of all Bessemer and open-hearth makers, and it is one of the most important. There is another view of the case. After a certain experience in comparing mechanical tests, which are comparatively easily made, with the more costly determinations of manganese, phosphorus, etc., the expert will not need to analyze every charge. He will learn to read manganese, approximately, in an elastic limit test, just as the expert blacksmith can now read carbon quite accurately by the water-hardening test. Herein will lie one of the values of the combined mechanical and chemical tests, that they will supplement and prove each other.

When the proper amounts of carbon, manganese, silicon, etc., for certain uses are known, it will not be impossible to approximate to them, in the Bessemer process, to a very helpful degree, and in the open-hearth and crucible process, to a reasonably accurate degree. Of course, the character of the ingredients must be much more definitely known than at present, and numerous batches of nominally the same ingredient, such as pig-iron, blooms, or puddle-balls, must be mixed, so as to largely dilute any high degree of impurity which any one batch may contain.

The thing first in order is, of course, to ascertain the mechanical properties of all grades of steel—not merely the individual resistances to destructive strains, which are but the stones that compose the mosaic, but the resistance within the elastic limit, which is the finished picture. To this end experiments like those of Sir William Fairbairn are indispensable, but to these must be added analyses of every grade of steel that can be produced, or the character of the metal is but half known.

In the present state of constructive and metallurgical art, it thus seems not only vitally important, but highly feasible, to increase in a large degree the uniformity of all grades of steel, and to make grades adapted to all special uses, instead of following the hit-or-miss and large-margin system, or want of system, that now obtains. Of course, the change must come slowly, and its early stages will be attended with difficulty and expense; but there can be no question as to its ultimate success and its immense advantage in constructive and manufacturing engineering and art.

What probable expense of experimenting is to be considered when it will increase, possibly double, the resistance of metals to specific stresses, and decrease the present enormous margin of safety? It seems unaccountable that government commissioners have so long neglected the chemical half of the problem—have so long neglected to complete the circuit, so that the metal will tell us its own story.

New Method of Developing Magnetism.—Tommasi has recently stated in a paper communicated to the French Academy of Sciences, that when a current of steam under a pressure of five or six atmospheres is driven through a copper tube one-eighth to one-quarter of an inch in diameter, wound in the form of a helix, a bar of iron placed in the axis of this helix, becomes so strongly magnetized that a needle placed several centimetres distant from this *steam-magnet*, is decidedly attracted. The magnetism remains in the bar so long as the current of steam continues.

WATER SUPPLY AND DRAINAGE.*

By W. A. CORFIELD, Esq., M.A., M.D.

II.

COLLECTION AND DISTRIBUTION OF WATER.

Having found a sufficient supply of good water, or a sufficient supply of water that can be purified on a large scale by filtration—a subject which we shall consider further on—or by means of Clarks' process, which I have described to you, or by both combined, we come to the modes of collection and distribution, which vary very much as to the site, sources, &c. One of the oldest plans, and for all that one of the best, is the eastern or Roman plan, if you like so to call it, which is that of tapping natural springs at their sources, or lakes, above the places to be supplied, and conducting the water by channels or aqueducts above or below ground, or alternately above and below, as occasion may require ; collecting it in large cisterns, allowing the sediment to settle, and then distributing by means of gravitation.

In later times we can adopt the same plan, and distribute either by gravitation or by steam power as we choose. Permanent springs at a distance may be conveyed by the Roman plan through channels across the country, covered the whole way right up to the distributing reservoirs or tanks. The conduits may be built of masonry and cement, like the Roman aqueducts, embedded in puddle, or they may be earthenware pipes, in which case they must be laid in watertight trenches, and jointed securely, or the water may be contaminated in various ways, and much of it may be lost, or the pipes may be of cast-iron, and this should be the case where deep valleys have to be crossed by means of inverted syphons.

Earthenware pipes are not strong enough to be used as inverted syphons. The rule is, that if the fall is greater than 1 in 300, then cast-iron pipes should be used. The fall of these conduits should be 5 feet in a mile, if they are of something like 2 feet in diameter, which is of a small size. If larger, it may be less, down to 1 in 10,000, or 6 inches in the mile. That is the fall of the New River conduit that supplies part of the north of London with water.

The velocity of the water should not be less than one foot in the second, so that it may move at a sufficient rate, nor greater than four feet in a second, for fear it should wear away the course by carrying down stones, etc. As an opinion about this plan, which I am going to describe to you at greater length, I may mention that Mr. Rawlinson stated, in a discussion on the water supply of Melbourne, which you will find reported in Vol. 18 of the proceedings of the Institution of Civil Engineers, that "he thought the plan of gathering spring water in Great Britain, by means of earthenware pipes to some common storage reservoir, was one that might be favorably looked at; the modern means of making earthenware pipes offered many facilities; and where springs were at a sufficient elevation and tolerably permanent, the water might be collected and brought into a covered reservoir on the Eastern plan. There were situations where that plan might be preferable to making an impounding reservoir."

Now, I should like to give you a short account of some of the points which are to be observed in the Roman aqueducts at Rome ; and afterwards I propose to give you an account of some extremely remarkable Roman aqueducts which are very little known, and which have been very seldom described, to wit, the aqueducts with which the town of Lugudunum, now called Lyons, was supplied, which aqueducts have some very interesting and instructive points about them, as you will see directly.

As I think I told you before, Rome was supplied by nine aqueducts. The first two were built entirely underground for their whole length, because the water supply might otherwise have been cut off in case of invasion. The more ancient of these two, the oldest of all the

* Abstract of lectures delivered before the School of Military Engineering at Chatham.

nine aqueducts, ran for a distance of about 11 miles. I need not say anything more about that one. When the Romans built the third aqueduct they were, it appears, no longer afraid of its being destroyed by enemies, and so they built it partly above ground, and partly underneath the ground. By the direct road to the place from which they took the water was 39 miles from Rome. Three thousand men were set to work at it under the Prætor Marcius, and so it has been called the Marcian aqueduct. This aqueduct was made so strong that the two succeeding ones were built on the top of it, so that you have the three channels one above another. The size of the channel of the Marcian aqueduct was about 5 Roman feet high by $2\frac{1}{2}$ wide.* The thickness of each of the sides was a foot. You can see this aqueduct outside one of the gates of Rome at the present day.

On these aqueducts there were ventilating shafts. There were also what are known as piscinæ, or small settling reservoirs. These piscinæ I shall describe to you a little further on. Then the base of the channel was broken up by inequalities, partly to help to break the very considerable fall, and likewise to aërate the water by agitation.

I may now say a word or two about the water supply of the Roman town of Lugudunum, in Gaul. In the first place, I must remind you that those aqueducts which supplied Rome with water were carried across no deep valleys, they had, it is true, often to be supported on high arches,because they pass over low ground, and the Romans have over and over again been blamed for not using syphons ; it has been said that the Romans were not acquainted with the properties of water, in that they did not use syphons in these aqueducts. We shall see directly whether that is true or not.

The town of Lugudunum (Lyons) was supplied by water by means of three aqueducts. The first of them was built in the first century before Christ, and here is the description of it in a few words. It had two branches, which united at a particular place. It passed over a large plateau in a straight line ; then went underground. Emerging from beneath the ground, it descended, by means of inverted syphons, into a deep valley, and was received at the bottom of that valley on a supporting bridge of arches. It was thus carried across the valley, and ascended the other side into a reservoir. So you see in the course of this aqueduct, which was built in the first century before Christ, there was a large and deep valley crossed by means of inverted syphons, by the very method which we employ now; and this shows you that the Romans then certainly understood and perfectly well appreciated the properties of the syphon.

I will now give you a description of the second aqueduct by means of which Lugudunum was supplied with water.

It was under ground the whole way, and it carried the water to a greater height than the other. The reason that it was constructed at all was, because the water was required to be carried to a greater height than the former aqueduct brought it. It was very nearly the size of the Marcian aqueduct. It was built of cubical stones placed together, as I may tell you a great many of these aqueducts were built. The stones were placed together without cement, and they fitted so accurately that some aqueducts built in this way are not even lined with cement. This aqueduct is in all probability intact at the present day for three-fourths of its length. Now we come to the third, which is the most important of the three, and which is, perhaps, the most remarkable Roman aqueduct of which we have the remains anywhere. The two former ones did not bring the water to a sufficient height. There is at Lyons an abrupt hill (Fourvières), on which several Roman palaces were built, and it was necessary to bring water to these. The Emperor Claudius, who was born at Lugudunum, and who lived there, determined to bring water on to this hill. He had already made an aqueduct for Rome (the Claudiun aqueduct), and so he knew something about it.

He had not used inverted syphons however, in his aqueduct at Rome, and for the simple reason, as you will presently see, that it was practically impossible; but he comes and orders a new aqueduct to be built for the city of Lugudunum, and it is that one which we

* The Roman foot was equal to about 11.65 English inches.

are now going to consider, as briefly as possible.

This aqueduct descended in the first place into three or four valleys on its way. The aqueduct was 52 kilometres long, including the syphons. It had 17 or 18 bridges of arches to carry it over low grounds, and four bridges to carry the syphons across the valleys.

And now I may tell you the size of the two more important of these valleys. The valley of the river Garon, which is the second one it had to cross, is 120 metres deep, and 800 metres broad. The valley of Bonan ———, which is the next, and which is the place at which I examined the aqueduct very carefully some time ago ————, is 139 metres deep, and 1,060 metres across between the two reservoirs, which are placed one on each side of the valley. So you see these are two very considerable valleys that had to be crossed.

And now, how did the Romans manage to effect their purpose? Bridges were out of the question, although we know that they built splendid aqueduct bridges, where possible, in such situations, as witness the well-known Pont du Gard, near Nismes, which had three rows of arches one above another, supporting the channel, and which is even now so perfect that it is about to be utilized for the purpose for which it was originally built.

They used inverted syphons. I told you that earthenware pipes will not do for syphons. Cast iron pipes need to be employed for large syphons. The Romans could only work iron on a small scale and so used leaden syphons. One thing they did, and which it is important to note in this: the water was brought up along the single channel of the aqueduct—the *specus*, as it was called—which in this particular one is about 2 Roman feet broad by 6 high, into a reservoir. This reservoir had some such dimensions as 5 yards by nearly 2, and the walls were about a yard thick; there was an opening in the roof for the purpose of cleansing, and on the front side of the reservoir (the one facing down the valley), there were several holes into which the leaden pipes were fixed. Now one of these valleys had 8 leaden syphons, another 9, and another 10; and the object, of course, of dividing the water in this way was that they might get pipes that would resist the enormous pressure, and if a pipe burst the rest might remain sound, so that only part of the water would be lost. Delorme, I should tell you, has calculated that this single aqueduct brought 11 millions of gallons of water into the place in 24 hours. It is hardly likely that it brought so much as that, but it certainly brought a considerable amount.

The interior of the channels was usually constructed of very small stones carefully placed, and generally laid in cement. There was in this particular one —and probably it was so generally—a layer of cement along the walls of the watercourse, and another layer, a considerably thicker one, along the base of the channel. The arches of the bridges were built of enormous rectangular blocks of stones, and the pillars broken at certain intervals by layers of brickwork buried in cement. The whole of the exterior of this was covered over with the work known to engineers as the "opus reticulatum," which is made of cubical pieces of stone, fitted carefully together so as to give an appearance such as that indicated in the drawing (like a chessboard set up on one corner).

There is another curious thing to observe, and that is that the syphons were provided with little tubes, or valves, to let out any air that might be carried down from the height by the water, and which might otherwise break the pipes. In the smaller valleys there were small leaden tubes, which rose up from the lowest part higher than the reservoirs, and in the larger ones weighted valves were used for the same purpose. But what I want you to see in this is, that by the time the Romans constructed even the earliest of these aqueducts at Lugudunum, they knew perfectly well the properties of water. They knew perfectly well they could make it travel up to the top of a hill if it had come down a slightly higher hill on the other side of a valley. Now I just wish to give you the height of the reservoir on the one side of the valley of Bonan, the deepest of them all. The height of that reservoir above the level of the Saone at Lyons, is 151 metres, or something over that. At the other side of the valley

into which the water was received the reservoir was 143 metres above same level, that is to say, the difference in height between those two reservoirs was only eight metres. In another case, it was 9 metres. Not only then did they understand these matters so well as that, but they actually lessened this amount by causing the syphons to enter nearest reservoir—the one nearest the place to be supplied—high up close to its roof, so that they actually thus diminished the pressure by at least a metre. I have given you this description at such length, because it shows how much we have to learn from what has been done a very long time before our own age, and also because there are so few descriptions of these splendid aqueducts.

We now come to the next plan, that of having a large drainage area, and of collecting the water from that area into an impounding reservoir. Before I begin to describe this, I will give you a brief account of one or two important impounding reservoirs. The first one will be that of the Rivington Pike reservoir, which now supplies the town of Liverpool with most of its water. This Rivington Pike reservoir is calculated to supply 21 millions of gallons of water per day to Liverpool, and it has 481 million cubic feet of contents, with a drainage area of $16\frac{1}{4}$ square miles; its embankment is 20 feet high. You will see from that, that it is calculated to contain 150 days' supply.

Then there is a reservoir which was made to supply Melbourne with water, the particulars of which are given in the volume from which I quoted to you before, namely, Vol. 18 of the Proceedings of the Institution of Civil Engineers, in a paper by Mr. Bullock Jackson. It is called the Yan Yean reservoir. The description runs thus:

"The Yan Yean reservoir was formed by throwing an embankment across a valley between two spurs of hills; thus retaining the rain-water which falls on the natural basin, as well as the flood-water which is led into it in winter from the Upper Plenty River; the river itself and the artificial watercourse forming, in the latter case, a vehicle for its conduction. The area of this reservoir, when full, is 1,303 acres; the greatest depth is 25 feet 6 inches, and the average depth not less than 18 feet. Its contents measure nearly 38,000,000 cubic yards, or upwards of 6,400,000,000 gallons. The area of the natural catchwater basin, independent of the reservoir, is 4,650 acres; so that, including the area of 600 acres drained by the watercourse, there is a direct drainage into the reservoir of 5,250 acres. . . . The original surface of the ground at the site of the Yan Yean reservoir consisted of a stiff retentive clay; the site was, therefore, admirably adapted for a reservoir. Prior to the commencement of the works, about two-thirds of the whole area were densely timbered with large specimens of eucalyptus, which were taken up and burnt. The sides of the reservoir, excepting in two parts, rise in a steep slope. The embankment is 1,053 yards in length at the top, and 30 feet 9 inches in height at the deepest part; the width at the top is 20 feet; the inner slope is 3 to 1, and the outer slope 2 to 1. The inner slope is pitched with rough stones from 15 to 20 inches deep. Along the centre is a puddle bank and puddle trench, with an inner apron and check trench. The puddle trench and bank are unusually thick, because, in the first place, almost the whole of the material used in the construction of the bank was clay, so that it entailed little extra expense; but principally, because previous to the works being commenced, the site of the embankment was occupied by trees of a gigantic size, with long straggling roots, which were all grubbed up, and which it was feared might leave clefts in the soil."

According to Mr. Hawkesley, the considerations that you have to take into account in constructing impounding reservoirs are these: In the first place you have to consider the extent of the drainage area. In the second place, the amount of rainfall. And in the third place the quantity of rainfall which can be collected into any reservoir which it is practical to make in the district. The size of these reservoirs must be proportioned to the population to be supplied, their area often requiring to be $\frac{1}{20}$ of the area of the water-shed. Mr. Hawkesley stated in a discussion, that he considered on an average of years that 30 inches of rainfall out of a rainfall of 48 inches, could be collected in an impounding res-

ervoir. It is usually considered that one-sixth part of the total rainfall must be put down as lost every year by floods that you cannot store. The water that you cannot collect is, of course, lost by evaporation from the surface of the ground, absorption by plants, and so on.

Now as to the site of the reservoir. In the first place steep-sided valleys are the best situations. In the next place, it is necessary, of course, that the place for collecting and storing water should be sufficiently high above the place to be supplied, so as to enable you to supply water by gravitation, and necessary also, that it shall not be too high above it, so that you may not have too great a rush of water.

Then besides the situation, the incline of the rocks must be considered. It is especially important in limestone that the dip of the strata shall be in the direction in which the water is running, because if the dip is against it you very often have immense quantities of water lost, disappearing between the strata and running away in another direction. Stiff impervious clay or compact rock affords the best situation. Trial shafts or borings require to be made at various places, it being better to make shafts than borings, to see if you have a sufficiently impervious material for the bed of the reservoir, and a sufficient depth of it. It is only with small reservoirs, as a rule, that you can safely puddle the whole of the bottom, or that it is done, and for this reason in small reservoirs the site is of less importance, as you can puddle the whole of the bottom, and carry it under the embankment of the puddle wall.

The embankment should have constructed what is called a puddle wall down the centre of it. I shall do well to give you some rules about this. Mr. Rawlinson lays it down, that the puddle wall is to be a foot thick at the surface of the ground for every three feet in height of the embankment, that is to say, that in an embankment 100 feet high, the puddle wall should be about $33\frac{1}{3}$ feet thick at the base. Then it slopes up to the top so as to be about four feet broad at the top. Having decided the thickness that you are going to make the puddle wall by the height that you are going to make the embankment, according to that rule, you have then to dig what is called a puddle trench. This is dug down to a considerable depth into the impervious bed that will be the bottom of the reservoir. The trench is usually sunk with sides sloping towards one another, though this is considered by some authorities to be an insecure plan. It would involve a considerable amount of extra work, which would to a great extent be unnecessary, to sink the puddle trench with sides diverging from one another, as you would expect it ought to be, and so it is sometimes recommended to sink the puddle trench with perpendicular sides. If it is very wet at the bottom of a puddle trench, it is usual to begin filling it with Portland cement concrete, and then to go on with the puddling. For puddling only the stiffer kinds of clay are used. On each side of the puddle wall a masonry wall is built, about equal to it in thickness. The example I gave you was one in which the embankment slope on each side of this puddle wall was pretty correct, namely, three to one inside, and two to one outside. This embankment is made of such materials as can be obtained in the neighborhood, and the whole embankment must be made in very thin layers, and should be trampled in as much as possible. The inner slope of the embankment is shingled up to a little short of the water-mark, and from that point it is pitched with blocks of stones. It is sometimes necessary to make minor embankments across valleys that may join with the one you are going to make into a reservoir. Now a reservoir requires a waste weir for the storm waters. This is generally made round the end of the embankment, or cut into the hillside. The water is carried from this point down to the old stream-course, and the channel is puddled until you are well clear of the embankment.

I have one or two words to say about the reason for the existence of these impounding reservoirs, and also about the size which it is necessary to make them, and the rules that are laid down for the amount of water that they should hold. In the first place, they are necessary where a sufficiently copious and permanent supply cannot be got from a river or large stream, or from artesian wells,

in order to secure a constant supply of water throughout the year, and they do this by storing the extra supply of water during floods, so that it may be saved for use in times of drought; secondly, they allow a settling to take place; and, in third place, they are necessary to prevent damage to the lower lands by floods, for great damage is occasionally done by the floods, even of such rivers as the Thames and the Severn, and, of course, great quantities of water are wasted.

The size must depend upon the amount of water required, and upon the permanence of the supply; we have reckoned the requisite supply at thirty gallons per head per day. Impounding reservoirs should, according to the opinion of many engineers, hold a six months demand. You can tell how much that is, if you will lay down the amount of gallons which you intend to supply per head, and the population to be supplied. If possible, the gathering-ground that supplies these reservoirs should be so large that the least available annual rainfall is sufficient for the supply; and then the reservoir should contain an excess of six months demand over six months least possible supply; that is to say, supposing the least possible supply at any time during the year is zero, then the reservoir must contain six months demand. The reservoir must be (to put it in Mr. Hawkesley's words) "sufficiently large to equalize all the droughts and floods to which the country was subject. Occasionally, but not very frequently, there might be a great excess of downfall, resulting in floods as large as three or four hundred times the minimum volume." Now the minimum volume is only about an 18th or 20th part of the mean volume, so it follows, that the floods are only 15 or 20 times the mean volume.

Now with regard to compensation. It is necessary in many instances to compensate owners, mill-owners, and others, people who are interested in the streams that you are going to impound, and, on an average, it is found that in England one-third of the amount of water requires to be given as compensation to these people, and, therefore, two-thirds remain for the use of the town. This compensation, of course, must be considered in determining the size of the reservoir. Sometimes it has been arranged that the amount given to the owners on the banks should be the average summer discharge, minus the floods, and sometimes special compensation reservoirs have been built to collect the water from a certain portion of the drainage area, these compensation reservoirs being entirely under the control of the persons who are to be compensated. However, you may take it as an average, that about one-third in England generally goes to them.

The culverts have been commonly built through the embankment in the made earth. This is stated to be a bad plan. Mr. Rawlinson says they should always be built in the rock or in the solid ground, and not in the made earth. The water tower is generally built just inside of the embankment, and the discharge or outlet pipes open into it with valves, which valves ought to be inside the embankment, and not outside of it. What are called "separating weirs" have been constructed in some reservoirs. They are ingenious contrivances by which the water, when at its ordinary height, flows over the weir into the culvert to be taken away to the town. When it is in flood, the force with which it comes enables it to pass over the opening leading to the culvert, and to get away into the old watercourse. "Feeders" for diverting streams into the reservoir are also sometimes necessary. It is often found to be necessary to cut a new course for the stream that runs down the valley, especially if it be a very large stream, or if it be a stream that is liable to floods.

I see that I forgot to mention one point, which I should have stated at the beginning of the lecture, with regard to the situation of these reservoirs. The site must not be too low, for if it is, the reservoir is necessarily too shallow, and shallow reservoirs are very bad, in that the water cannot possibly be kept pure, it being perfectly impossible to store it and keep it pure in shallow reservoirs. If the ground is too high, and no other suitable place can be got, then it is necessary to make what are called "balancing reservoirs," so that the force of the water may be broken by its being kept in a series of reservoirs at different levels.

I do not profess to have given you the engineering details, as you will plainly see. All I have tried to do is to give you some of the most important points, according to the best authorities that I have been able to find.

The channels are generally made of masonry or brickwork. The water-way is, according to Rankine, best semi-circular, or a half square, or a half hexagon. These channels are usually made cylindrical ; they require ventilating shafts after the custom of the Romans. Occasionally they are made with an egg-shaped section, like large sewers.

Channels require to be curved at their junctions, or at any rate, they require to be joined at very acute angles.

With regard to aqueducts, Mr. Rawlinson tells us that "aqueducts of iron will probably be cheaper than masonry or brickwork constructions." They have been made self-supporting by Mr. Simpson, by constructing them in the form of tubular iron-girders.

Now, with regard to the fall of these channels, I gave you one or two points before, when considering the pipes conveying the streams. In the discussion on the water supply of Paris, in the 25th Volume of the Proceedings of the Institute of Civil Engineers, Mr. Bateman gave the following example with reference to the Loch Katrine aqueduct of the Glasgow Water Works: "The fall was 10 inches to the mile throughout, except where the water was carried by syphon pipes across deep valleys, which, in one instance of a hollow of 250 feet, was done for a distance of 3½ miles, and in these cases there was a fall of 5 feet per mile, to economize the size of the pipes."

This aqueduct, I believe, is about the largest that has been constructed. The channel is cylindrical, and about 8 feet in diameter. Mr. Rawlinson said in the same discussion, that "the fall of an aqueduct must be in proportion to the depth and volume of water which it had to deliver. The fall of the New River in London was 1 in 10,000, or 6 inches to the mile, but with so large a volume, and an unpaved channel, it was necessary to form a weir, and give the water a vertical fall of a few inches at certain points of its course. He found that plan was adopted in the East. In laying out a line of aqueduct two principles were involved. If it were graded, as the Romans graded some of theirs, from 5 to 15 feet per mile, there would be difficulty in stopping the water at any point. It was practicable, however, to grade an aqueduct having a fall of 15 feet or 20 feet per mile, if vertical falls were introduced at intervals, alternately with level or nearly level lengths. This mode enabled an engineer to fix the velocity, so as to prevent undue washing. The vertical falls tended to aerate the water, and this in itself constituted an additional advantage. All covered aqueduct conduits should be abundantly ventilated, and there should be side entrances, stop gates, overflows, and wash-out valves." Sometimes in aqueduct bridges, the sectional area of the channel is diminished, and the gradient made steeper. This, of course, gives greater velocity to the water, and a smaller amount of material is required, and so less expense incurred in constructing the bridges. So much as to the masonry.

Now as to pipes. Earthenware pipes are made up to about 3 feet in diameter. If they are of compact glazed earthenware, they are very tough and strong, but they will not bear shocks, either the shocks of water or anything else, and they cannot be jointed so as to resist a great pressure, and so are not suitable for syphons. We will not say anything more about lead pipes, because they are not now used for this purpose. Cast iron pipes, Rankine says, should be of a uniform thickness; and he lays down the following rule for the *minimum* thickness: "The thickness of a cast iron pipe is never to be less than a mean proportioned between its internal diameter and one forty-eighth of an inch." But, he adds, "it is very seldom indeed, that a less thickness than ⅜ of an inch is used for any pipe how small soever." Large cast iron pipes are liable to burst, and there are some instances on record of it; one in the water works for the supply of Melbourne, which I have already mentioned once or twice, in which case the pipe was 33 inches in width, was laid through the embankment of the reservoir and burst. Now this is what Mr. Hawkesley said in a discussion on the subject at the Institution of Civil Engineers, about the bursting of cast iron

pipes: "Cast iron in the shape of a pipe would stand little unequal pressure externally, although such a pipe would bear an enormous pressure when equally distributed, whether applied externally or internally, and most in the former case, as the metal then would be under compression," and he went on to say, that at "the Rivington Pike reservoir of the Liverpool water works two lines of pipes were carried through an embankment 20 feet high, at a distance of 16 feet from the top of it. They were cast iron pipes, each pipe being made in 10 or 12 pieces, and they are the largest pipes that have been laid, each pipe being 44 inches in diameter. Now, out of these two lines of pipes, fully one-third of the pipes so placed, which were excellent castings, were broken, although they borne a pressure of 300 feet internally. The fractures invariably occurred at the top and bottom, and not at the two sides as might have been expected. The pipes being flattened and distorted by the pressure of the earth, were subjected to a strain at the top and bottom greater than at the sides, and were undoubtedly broken by compression. This fact convinced him, that pipes in that position were very insecure. Commonly, in similar cases, there was a pressure of water on the inside, and a pressure of earth on the outside; and it was a usual arrangement for the valve which shut off the water to be placed under the embankment," (that is a point I have referred to as one of considerable importance), "so that if a pipe became ruptured when in use the water would escape into the embankment, and if it found its way to the back of the puddle, the embankment would be torn down, and the whole of the water in the reservoir set free. It was not, therefore, desirable that large pipes should be laid under an embankment, where they would be subject to a considerable pressure of earth."

When a pipe of that magnitude breaks it usually does great damage. In one of these pipes that I have just mentioned to you, sixteen million gallons of water were capable of being discharged daily, and if an accident occurred, there would be a column of 44 inches in diameter, acting with perhaps 200 or 300 feet of pressure to be dealt with. Another thing about these large pipes is, that there is a considerable difficulty in repairing them. One length of these weighs about 4 tons, so that they cannot easily be dragged about or taken up. Now, cast iron pipes are said often to break from the pressure of the air. Whenever air gets driven in along with the water, and especially so in syphons where valleys are crossed, these pipes are broken (it is said) by the collection of compressed air.

Mr. Hawkesley tells us, that he considers that they are broken when the air is let out; that it is the shock caused by the running together of the two separated parts of the water that causes the breakage of these pipes, when the compressed air that is collected in them is let out too suddenly; and he recommends, and has practised in the case of those large mains at the Liverpool water works, the adoption of valves with an aperture of only $\frac{3}{4}$ of an inch; through these the air rushes out, but they do not permit the columns of water to come together very suddenly; there should be one of these at each place throughout the channel where the pipe is higher than the theoretical line, or than the line of the fall. At each one of these places air is liable to accumulate and to become compressed, and, perhaps, to burst the pipe. At each one of these places, therefore, there should be means of letting out the compressed air, and even with regard to this precaution we were, as I showed you before, forestalled in the aqueducts of the ancients.

Pipes are also sometimes burst by the pressure of the water when a valve on the main is closed; this difficulty has been overcome by a plan mentioned by Mr. H. Maudslay at the Institute of Civil Engineers: "In some instances there had been a small valve and pipe, so placed at the side of the large main as to join the main both before and beyond the large valve, in order that the whole body of water might not act like a water-ram on the closing of the large valve. This plan has been adopted in the Neptune fountain at Versailles, and also, he believed, in the mains supplying the fountains at the Crystal Palace. On shutting the large valve, the main flow was stopped, but the small pipe permitted a continuous flow of the smaller

quantity, and thus the danger of bursting was avoided. The second valve was afterwards closed gradually. He thought that this was the most simple plan that could be adopted, and perhaps the least costly, while it was certainly very effective." Another plan is that described by Mr. Hawkesley, as follows: "The value upon the main at Liverpool was divided into three openings, each of which was provided with a separate screen, so that by raising or lowering each of these slowly in succession the water was either admitted or turned off very gradually. The object of dividing the valve into three apertures was to enable a workman to operate with facility on any one of the screws. In large pipes, where the pressure was great, it was necessary, in order that the brass pieces, upon which the valve acted, might not be abraded, that only a certain amount of pressure should be put upon them, and that the friction under that pressure should not be greater than a man could overcome, by simply turning a handle, without stripping the thread of the screw. As a further provision the centre valve was made very narrow; the side valves were first closed and then the centre one, so that concussion was prevented. In addition there were branches at various points, upon which equilibrium valves, with a piston underneath, were placed, and others had double beat valves. But as these valves required to be heavily weighted, the inertia of the weight would, if other means were not taken, prevent the valve from rising so rapidly as was desirable. Therefore, between the weight and the valve there was a spring, the action of which was independent either of the valve, or of the weight, so that instead of the valve waiting for the large weight to rise, the spring immediately yielded under it and the water was discharged instantaneously. When these valves were used not the slightest shock was experienced. If there had been, the pipe would undoubtedly have been ruptured, for the length of the column, and the velocity, upon which the force of concussion was dependent, were both very great. That was another reason he preferred a smaller pipe. There were still, however, other precautions. Powerful disc-valves, made by Sir W. Armstrong & Co., and which acted in a similar way to the cataract apparatus if a small power steam-engine were placed upon the main. They were made to close slowly, being let go by a trigger. As a hundred million gallons might pass through the main in twenty-four hours, if a pipe burst, without any provision being made to stop the flow, a great deal of mischief would ensue. Supposing, however, a fracture to occur when the disc-valve was open, then the valve would gently close in about two minutes, and arrest the discharge. These valves cost £300 each. He had found them to act, on various occasions, extremely well, and but for them the country would have been flooded on several occasions."

Now, we have considered the Roman plan and also the plan of collecting water by drainage areas into large impounding reservoirs and conveying it by channels to the place that wants it, the place where it is to be distributed. When it comes there, it is collected in what are called service reservoirs. The most ancient examples of these service reservoirs are those very piscinæ, upon the Roman aqueducts, which I have spoken of, and you can see examples of them in Rome at the present day. The best I ever saw was at a place called Bona in Algeria, where is to be seen a set of the most magnificent service reservoirs. The plan was to have four compartments. The water was first let into one of the two upper ones; it then fell from that into one below, possibly over a waste-pipe. The water then passed, possibly through strainers, into another compartment on the same level, and it then rose through the roof of that compartment into a third at the level of the first one, out of which it went onwards, and a considerable settling took place. Now, there were means of scouring out these two lower compartments, which could be shut off from the upper ones so that the mud might be got out of them. The water, when it is brought to these reservoirs by either of these two methods, or when it is got into them, as it very often is now for the supply of large towns, directly out of the river, very often requires to be filtered, as mere settling is not enough for it. We have then to consider what materials are used for filtering the water,

what size the filter beds require to be, and what effect is produced on water by filtration.

Now, in the first place, the materials that are commonly used for filtration are sand and gravel. The different merits of sand and gravel and also of charcoal I shall have to consider in the next lecture, but I must conclude this lecture by telling you that the effect of filtration of water, even by sand and gravel, is not merely the mechanical effect of removing the suspended substances that the water may contain, but that, at the same time, there is a chemical action going on. This is on account of the air that is contained between the little particles of sand, which air is so brought into contact with the finely divided water that any substances in the water that are capable of oxydation do become oxydized, and a considerable amount of the organic matters in the water are thus oxydized, and transformed into inocuous matters. That is the first important point to understand about filters, whether in filtering water for drinking purposes, or with regard to a filter about which we shall have to say more after a while—a filter to purify sewer water.

I have shown you that it was a fallacy to suppose that the Romans did not understand the principle of the syphon, but that they constructed most admirable ones on the aqueducts that brought water to Lyons. It so happens, by a curious chance, that I have, recently, seen some plans and sections of the Roman aqueducts which supplied Jerusalem with water, and on one of those I find a syphon, not made with lead pipes, but a syphon made of stone. It is made of blocks of stone with a hole through each; the blocks are put together so as to form a continuous pipe. Each piece is cut at the end so that around the pipe itself, the aperture in the stone, there is a ring left projecting on the face of the stone, and that ring fits into a groove on the next stone. That made a sufficiently tight syphon to convey the water, without any great amount of leakage, to a considerable vertical depth and up again. The depth, as far as I can judge from the plans, is about 100 feet from the highest point to the lowest. Well, now, we get up to the point where the water has reached the town, and there I told you it is almost necessary, certainly usual, to construct a service reservoir. The Romans constructed them under the name of Piscinæ; and I told you, I think, in two words, how those were made; I now want to give you a rather longer account of their construction. The water that was brought by one of the aqueducts to Rome was taken direct from the river Anio, and the result of taking the water direct from the river was that after the heavy rains it was charged with mud, and though large cisterns were provided, in which, by an ingenious arrangement, much of the sediment was caught, still it was not considered satisfactory by Frontinus, who was the engineer and who, therefore, under his patron the Emperor Nerva, altered the source. Still the water that came to Rome required to have settling tanks, as described by Mr. Parker in a paper I quoted before, and from which I again quote:

"The building consisted of four chambers—two beneath and two above. Supposing, for the sake of illustration and in the absence of a diagram, the letters

A B
C D represent the four chambers. The channel of the aqueduct coming from the east, at a tolerably high level enters the chamber B. Thence the water passed (possibly over a large waste pipe) into the chamber beneath, D. Between D and C there were communications through the wall (possibly provided with fine grating). Through the roof of C there was a hole, and the water passed upwards, of course, finding the same level in A as in B, whence it was carried off into another stream. By the aid of sluice gates the water could be transferred direct from chamber B to chamber A, and access was obtained by an opening to the chambers beneath, and the mud was from time to time cleared out."

Just the same thing was the case at Lugdunum (Lyons). Large settling tanks have been found on the hill of Fourvieres, consisting of two reservoirs with vaulted roofs, thus described: One of them was 48 feet long by 44 feet broad, and 20 feet high, with two conduits to admit the water, and several round holes in the roof from which it could be drawn. The walls were 3 feet thick,

lined with very hard cement. A second was 100 feet long, 12 feet broad, and 15 feet high, divided by a wall into two chambers. A third was a large one, of which five of the supporting arches remain, and the discharge conduit, 1½ feet broad, which distributed the water, by means of leaden pipes (of which a specimen has been found) to the palaces, gardens, etc. In some cases similar constructions formed public reservoirs from which the people drew the water. In Rome "there were 591 open reservoirs (lacus) for the service of all comers. * * * These reservoirs were what we usually speak of as fountains; and some hundreds are in use to this day, many probably on the site of the older ones. There were very stringent laws respecting their use. Heavy penalties were inflicted upon any one dipping a dirty bucket or vessel into the reservoir. There were also laws respecting the 'overflow,' as the fountains, of course, were constantly running; these were the most important to keep in order, as all the poorer classes depended entirely upon them for their supply of water."

Now let us consider the Service Reservoirs as they are made now. Service reservoirs must either be placed at a low level, so that the water has to be pumped from them, or high up, which is better, so that the water, if not brought to them at that level, is pumped into them, as at Lyons, on the Rhone, where the water is brought to them at the highest point. They are made to contain a few days' supply. In the first place, they must always be covered; even the Roman ones were. The reason of there being covered is that, if not covered, the water becomes impure, for the impurities of the air dissolve in the water and the growth of confervæ is also, of course, very much aided by light. If they are at the level of the ground, they are built of masonry.

Mr. Rawlinson says, "The ground excavated for the foundation of a tank should be made perfectly water-tight. The bottom may be covered with clay puddle and the side walls be backed or lined with clay puddle. The thickness of the puddle should not be less than 12 inches. If the site selected for a tank is sand, gravel, or open jointed rock, great care must be taken to give the puddle a full and even bearing over the whole surface area; open joints in rock must be cleaned out and then filled up with concrete. In gravel, large stones must be removed and the entire surface brought to a level, smooth, and even plain. Clay puddle will only resist the pressure of water when it rests solidly on an even bed, so as to prevent the water forcing holes through it, which will be the case if there is a rough uneven surface and open space beneath." (*Suggestions as to the preparation of plans as to Main Sewerage and Drainage and as to Water Supply.*)

The roof is supported on piers with arches between them, and across sometimes iron columns are placed in rows supporting the girders which carry the arches. The supply pipe has one or more exits, a waste and a wash-out, which may be connected by valves so that the supply can be directly connected with the exit independently of the tank.

[Drawing exhibited.] That gives a general idea. The water is received in a sort of well or tower through which it passes into the tank, and after settling has taken place it passes out through a valve into the exit pipe. When the supply is too great it is carried off by an overflow to which the wash-out pipe may be jointed.

Well now, I should like to give you a more detailed description of such reservoirs, and I take as an instance, and that for several reasons, the description of some reservoirs with supply tanks:

"The reservoir of Passy is intended to receive the waters pumped from the Seine at Chaillot, and those furnished by the Artesian well of Passy when disposable; it is composed of three compartments, two of which are covered by a second range of arches, the third, intended as a reserve in case of fire, being deeper than the rest, and only of one story; the two upper ranges of arches, also, are to be made to hold a supply of water, one of them being covered and the other not. The united capacity of these various compartments is 9,227,097 gallons, and their levels above the Seine are respectively arranged at 150 feet, and 163 feet, above zero of the scale of the bridge of la Tournelle. The capacity of the separate reservoirs is, for those

nearest to the ground, respectively 2,232,800 and 2,344,984 gallons; these are covered with reservoirs of the capacity of 1,282,792 and 1,495,729 gallons; and the uncovered side portions of the reservoir are devoted to the remaining 870,792 gallons. These buildings are formed on the 'tuf du calcaire lacustre,' which afforded a hard, resisting foundation, and did not require any particular precautions to prevent the subsidence of the piers, or to secure the water tightness, or the impermeability of the bottom. The external walls have been in consequence carried down to the depth of 8 ft. 4 in. and have a width of 8 ft. 8 in. all around. The floors are of masonry, 1 foot thick in meuliere and cement, covered with a rendering coat of 1¼ inches of the same cement worked to a fine face. This is covered with a range of cylindrical vaults of 10 feet opening, springing from pillars 2 ft. 8 in. square upon the top, gradually enlarging to 5 ft. at the bottom. It is calculated that in no case does the weight brought upon a square inch of this masonry exceed 152 lbs. The thickness of the arch forming the roof of the first tier, and the floor of the second division, is about 1 ft. 2 in. on the crown; that of the roof of the upper division is only 4½ inches, executed in two courses of tiles bedded in cement, and 'rendered' with a coating of that material and covered with concrete.

"The reservoirs of Menilmontant are considerably larger than those of Passy, and being founded upon the upper members of the Paris Basin, special precautions were required to insure that the ground should not yield under the combined pressure of the masonry, and the 29¼ million gallons of water intended to be stored. The marls covering the gypsum of which the mountain of Menilmontant is composed, were not considered to be able to withstand that weight. The foundations of the piers were therefore carried lower down, and thence built in a description of rough rubble of menliere set in hydraulic lime. The bottom floor of the reservoir is arched over these piers, and the upper tier of arches rests upon this floor."

It is only fair to tell you that some engineers, and among others, Mr. Rawlinson, considered the plan of building two-storied reservoirs as a bad one, and not to be imitated; but it necessary to know that there is such a plan, and the description applies, to a great extent, to all reservoirs.

To take an example nearer us, there is Mr. Simpson's elevated reservoir on Putney Heath; that contains ten millions of gallons altogether. There is there a double covered reservoir to contain filtered water for domestic use, and a smaller open one to contain unfiltered water for the streets, and to supply the Serpentine, and so on. So that you see it is usual in these cases to build several reservoirs together. This covered reservoir that has to contain water for domestic purposes, is double, or constructed in two halves. Each part has an area of 310 feet by 160 feet, and a depth of 20 feet. The sides all round have a slope of one to one. This gives a mean area of 290 feet by 140 feet, and a capacity of about 5,075,000 gallons for each reservoir, exclusive of the space occupied by the piers. "Hence the whole capacity may be taken" as stated by Mr. Simpson in his evidence, "at 10,000,000 gallons. The sides of the reservoir are cut out in the form of steps, which are filled up with concrete to a uniform slope of one to one; and a bed of concrete one foot in thickness is also laid over the whole bottom; each half of the reservoir is covered with eight brick arches, averaging rather less than 20 feet span, the arches being each 20 feet span, and the others 18 ft. 8 in. Two piers supporting these arches are built lengthways, and are each 310 feet long at the top, and 270 feet at the base. The arches are each one brick in thickness, and are covered over with a layer of puddle, the haunches being filled up with concrete. The piers are carried out 14 inches thick; but the division wall between the two parts of the reservoir is rather more than four feet thick, with a concrete slope of one and a half to one on each side. The 14-inch piers supporting the arch are built with large circular hollows 17½ feet diameter. The centres of these circular hollows are 40 feet apart, so that solid brickwork 23 feet long is left between the circular hollows, supposing a horizontal section taken through the centres of the hollows. Each of the 23 feet spaces has a 14-inch

counterfort carried out at right angles. These counterforts occur at intervals of 26 feet and 13 feet alternately, and project 6 feet wide at the base, on each side of the pier, and run out to nothing at the top, or springing of the arches." "The versed sine or rise of the arches is 4 ft. 3 in., or rather more than one-fifth of the span. Each arch is provided with two openings in the centre, communicating with a line of 12-inch earthenware tubular pipe, which passes through the spandrils and communicates with perforated iron tops in the division wall between the two parts of the reservoir. By this contrivance the space above the water in the covered reservoirs is effectually ventilated. The supply pipe from Thames Ditton is 30 in. in diameter and comes into each part of the reservoir at the level of top-water, which is a few inches below the springing of the arches. At this level a waste weir, or overflow, is fixed to prevent the reservoir being filled too full. The exit mains to London consist of two 24-inch pipes, and they pass from the bottom of the reservoir, which has an inclination in one direction of 1 in 20, and a fall across of six inches." (Hughes on "Waterworks:" Weale's Series.)

Now a great reason for the existence of these service reservoirs is, that the hourly demand during the day varies very much from the mean. It is sometimes so much as three times the mean demand, during certain hours, so that by this means it is not necessary for the mains to be made inordinately large. But otherwise the mains would have to be made large enough to give the greatest demand, instead of being only sufficient for the mean demand. And this is the case if the reservoir is only large enough to contain half the daily demand. In that case the distributing pipes need only to be calculated to give the greatest hourly demand. These you will recollect are under ground tanks. Elevated tanks are sometimes made of cast iron, or wrought iron plates bolted together, and tied by wrought iron rods at the bottom, to one another. The supply, exit, and overflow pipes ought to be together in a corner of the reservoir, in a small separate compartment. This separate compartment is connected with the main reservoir by a valve, so that the main reservoir can be cleaned out and the supply go on independently of it. Thus you can shut out the supply, stop pumping, open a valve, and let out all the water from the large reservoir by the supply pipe to the town. Then you can close the valve and let the supply go on through this little separate reservoir, while the other is being mended or cleaned out.

The overflow pipe, or waste pipe, or whatever you like to call it, ought to open into an open channel, and not be connected, as is very frequently the case, with the nearest drain or sewer. It ought to open above ground, because as the reservoir is covered, if it does not do so, the foul air from the drain will come up that waste pipe, and be dissolved by the water in the cistern, and so you will render the water that you have taken so much trouble to get pure, you will render it impure, and that is what is continually done in all towns, and in houses, as I shall tell you presently when speaking of sewerage.

For distributing basins or tanks, Rankine says, that "the most efficient protection against heat and frost is that given by a vaulted roof of masonry, or brick, covered with asphaltic-concrete, to exclude surface water, and with two or three feet of soil, and a layer of turf." Mr. Rawlinson says, that "brick and masonry tanks, if arched, may be covered in with sand, or fine earth, to the depth of 18 inches, which will preserve the water cool."

Up to the present time we have been describing works connected with impounding reservoirs; now, with regard to river works. With river works you still more certainly require settling reservoirs into which water may either flow directly through culverts from the river, as it does at Chelsea, or into which it may be pumped. When the water flows in from culverts, you require almost invariably to have filter beds, which we shall describe a little further on. Sometimes for river works it is necessary to construct a weir right across the river, in order to keep the water as near as may be at constant level. The engine power employed ought to be considerably greater than that which is actually wanted, one-third greater at any rate, and of course there ought always to be

a reserve engine. At the Chelsea works, to which I have before referred, the depositing reservoirs are made in London clay, and the bottom and sides are merely lined with cement placed upon this clay. From this the water passes direct to the filter beds.

With regard to those cases in which the water is taken from rivers, there are certain things I want to tell you. I want to tell you something about the purification of river water. We know that into rivers, especially in thickly populated countries, an enormous amount of refuse matter of all sorts is thrown, and it is necessary to know whether this refuse matter is destroyed in its passage along the rivers, that is to say, whether the water, after running a certain distance, becomes sufficiently pure to be used for drinking. And now I must quote to you from a book from which I shall have occasion to quote a great many times during the course of the remaining lectures, a book entitled "A Digest of Facts relating to the Treatment and Utilization of Sewage."

"The evidence collected on this head by the Royal Commission on Water Supply was very various. Dr. Frankland says:

'There is no process practicable on a large scale by which that noxious material (sewage matter) can be removed from water once so contaminated, and therefore I am of opinion that water which has been once contaminated by sewage or manure matter is henceforth unsuitable for domestic use.'"

Now the results of experiments are found to give the following facts:—In the first place it appears that in rivers that are well known to be polluted, and the water of which has a temperature not exceeding 64° Fahrenheit, a flow of between eleven and thirteen miles "produces but little effect upon the organic matter dissolved in the water." To remove all uncertainty from the "variability of the composition of the river waters at different times of the day," experiments were made by mxing filtered London sewage with water; "it was then well agitated and freely exposed to the air and light every day, by being syphoned in a slender stream from one vessel to another, falling each time through three feet of air." The mixture which originally contained, in 100,000 parts .267 of organic carbon and .081 of organic nitrogen was found to contain, after 96 hours, .250 of organic carbon and .058 of organic nitrogen; and after 192 hours; .2 of organic carbon and .054 of organic nitrogen. The temperature of the air during this experiment was about 20 deg. cent. (68° Fahrenheit). "These results indicate approximately the effect which would be produced by the flow of a stream containing 10 per cent. of sewage for 96 and 192 miles respectively, at the rate of one mile per hour." They show then, that at the above temperature, during a flow of 96 miles, at the rate of one mile an hour, the amount of organic carbon was reduced 6.4 per cent., that of organic nitrogen 28.4 per cent.; while during the flow of 192 miles, at the same rate, the amounts of these two substances were only reduced 25.1 and 83.3 per cent. respectively. It is shown that the oxydation of this organic matter is chiefly affected by the amount of atmospheric oxygen dissolved in the water, "such dissolved oxygen being well known to be chemically much more active than the gaseous oxygen of the air."

It was found, however, that the action of this dissolved oxygen was not really anything like so quick or so perfect as generally supposed, and that 62 per cent. of the sewage was the maximum quantity that would be oxydized during 168 hours, even supposing that the oxydation took place during the whole time at the maximum rate observed, which was certainly not the case.

"It is thus evident, that so far from sewage mixed with 20 times its volume of water being oxydized during a flow of 10 or 12 miles, scarcely two-thirds of it would be so destroyed in a flow of 168 miles at the rate of one mile per hour, or after the lapse of a week. . . . . . Thus, whether we examine the organic pollution of a river at different points of its flow, or the rate of disappearance of the organic matter of sewage when the latter is mixed with fresh water and violently agitated in contact with air, or finally the rate at which dissolved oxygen disappears in water polluted with 5 per cent. of sewage, we are led in each case to the inevitable conclusion that the oxydation of the organic matter in sew-

age proceeds with extreme slowness, even when the sewage is mixed with a large volume of unpolluted water, and that it is impossible to say how far such water must flow before the sewage matter becomes thoroughly oxydized. It will be safe to infer, however, from the above results, that there is no river in the United Kingdom long enough to effect the destruction of sewage by oxydation.

Now there were several scientific men who gave evidence of another sort, and who declared that practically speaking water was sufficiently pure after even a short flow. The answer to that statement is found if we just go into a few of the public health facts. Here is one. This is gathered from Mr. Simon's report on the cholera epidemics of London in 1848–49 and 1853–54. "When the Lambeth Company took its water from the Thames near Hungerford Bridge, the people who drank that water died at the rate of 12.5 per thousand. When the source of supply was moved to the Thames at Thames Ditton, the mortality was only 3.7 per thousand, while at the same time, and in the same districts, the mortality among the people who were supplied with water by the Southwark Company from the Thames at Battersea was at the rate of 13 per thousand."

I could give you any number of facts of that sort to show you that water that has been polluted is dangerous to drink. I may just mention to you the opinion which Sir Benjamin Brodie, the late Professor of Chemistry at Oxford, has given; he said in his evidence before the Rivers' Pollution Commissioners:—"I believe that an infinitesimally small quantity of decayed matter is able to produce an injurious effect upon health. Therefore if a large proportion of organic matter was removed by the process of oxydation the quantity left might be quite sufficient to be injurious to health. With regard to the oxydation we know that to destroy organic matter the most powerful oxydizing agents are required: we must boil it with nitric acid and chloric acid, and the most perfect chemical agents. To think to get rid of organic matter by exposure to the air for a short time, is absurd."

I give you those statements in order to bring you to the conclusion to which I wish you to come, namely, that we should not take water for the supply of villages and towns, from a river that has been contaminated at all, if it can possibly be helped; that it has never been proved that such water gets really pure again; and that at certain times therefore very considerable danger may arise from drinking such water; in fact as Mr. Simon said when examined before the Royal Commission on water supply "it ought to be made an absolute condition for a public water supply that it should be uncontaminable by drainage."

The water when taken from the river, or even if it is taken from the gentle slopes of cultivated lands, and also in some other instances, requires to be filtered as well as allowed to settle; deposition is not sufficient of itself. It is important, also, to keep out inferior waters, that is when there are several sources; and with this condition, you may prevent the necessity of the water all requiring to be filtered.

Mr. Parker says:—"At last it may be interesting to know what Frontinus did, or rather, what he says with becoming modesty, his patron, the Emperor Nerva, accomplished on this score: 'But the water of the Anio Novus often spoilt the rest, for since it was the highest as to level, and held the first rank as to abundance, it was most often made use of to help the others when they failed. The stupidity, however, of the Aquarii was such that they had introduced this water into the channels of several others where there was no need, and spoilt water which was flowing in abundance without it. This was the case especially as regards the Claudian, which came all the way for many miles in its own channel perfectly pure, but when it reached Rome and was mixed with the Anio it lost all its purity. And thus it happened that many were not in fact helped at all by the addition of the extra water, through the want of care on the part of those who distributed it. For instance, we found even the Marcian, the most pleasant *to drink* on account of its brightness and freshness, in use in the baths, and by the cloth-fullers, and according to all accounts employed for the most base services. It pleased, therefore, the Emperor to have all these separated, and for each to be so arranged

that first of all the Marcian should be assigned *to its own use*, so that the Anio Vetus, which from various reasons was found to be less wholesome, as well as being at a low level, should be employed for the watering of the gardens in the suburbs, and in the city itself, for viler purposes.'"

So you see they had, even then, found out that one water was more wholesome than another, and when they had got supplies from two or three sources they knew it was better to keep them separate, and so use the best one for drinking purposes and the inferior ones for other purposes.

Now when water containing substances in suspension is passed through a medium provided with fine pores, it is, of course, at least the purer by virtue of the removal of all such matters as are unable to pass through the pores. If that were all that filtration accomplished, it would be only a fine straining process. But that is not all. If you take a large quantity of porous material, for instance, a large mass of sand, or gravel, or especially charcoal,—almost any porous material,—and pass water through it, water containing certain substances in solution, and certain substances in suspension, those in suspension will remain unless they are fine enough to pass through the pores of the material. But all these porous substances contain an immense amount of air between their pores, and the water by being passed through them is divided into an infinite number of exceedingly small rivulets, exceedingly small streams, and so the substances in solution in the water are brought into the closest possible contact with the oxygen of the air between the pores of the filtering material, and so when you have passed the water through a filter, a chemical action takes place, and not merely a mechanical action. You have a mechanical action first, and then you have also a chemical action. That chemical action consists in the oxydation of the substances held in solution in the water—that is, such substances as are capable of oxydation, and these are the ammonia and the putrescible organic matters which are so dangerous when left in drinking waters.

One of the best filtering substances, that is, one which alters the substances contained in water most in its passage through it, is animal charcoal, and you will find in the 26th and 27th Vols. of the *Proceedings of the Institution of Civil Engineers*, a most important and interesting discussion on this property of animal charcoal, and other substances—sand, and so on—upon the power of these materials to cause the oxydation of substances in water. I should tell you that the paper itself to which I refer in that 26th vol. is not worth reading, but the discussion afterwards is very well worth careful study. The paper is worthless, because it came to an entirely erroneous conclusion on account of the experiments being performed by a process which is practically worthless.

Here I must give you an example. Dr. Frankland tells us that he filtered New River water through animal charcoal; that before filtration it contained in solution about 18 grains in a gallon of solid matters, that after filtration it contained 11.6. Of course you are prepared for a less amount of impurity after filtration. Now the organic and other volatile matters contained in the water before filtration amounted to .37 of a grain in a gallon, and after filtration the amount was 15; that is to say that more than one half of these matters were removed by filtration through animal charcoal. After a month this charcoal removed still more organic matter, and some mineral matters as well, and even a few months afterwards one half of the organic and volatile matters only remained after filtration. These experiments show a very important thing, which is perfectly true of a sand filter as it is of an animal charcoal filter, and that is, it is not by storing up these matters that a filter works, or else it would be of no use whatever to make a filter. You would have it choked up in a very short time, and it would continually have to be renewed, whether made of sand, of gravel, of charcoal, or what not. It is by oxydizing the substances that the advantage is obtained, and the results of oxydation you can find in the water afterwards, and these results of the oxydation are nitrates and nitrites, and carbonates. Of course these are harmless matters, and that is the important action which a filter has. Dr. Frankland stated that he had passed the water supplied to

London by the Grand Junction Company through a thickness of three feet of animal charcoal, at the rate of 41,000 gallons per square foot per day of twenty-four hours, under a head of water of thirty feet, the charcoal being in granules like coarse sand, and that at that rate—a tremendous rate—more than one half of the organic matter was removed. He thought from these experiments on animal charcoal that persons who had to supply water to towns ought to use it, as at any rate one of the media in the filter beds. I must not pass from charcoal without mentioning that vegetable charcoal is agreed on nearly all hands to be almost entirely useless for purposes of filtration. In the first place it contains enormous amounts of salts which are soluble in water, so that the water becomes very much harder in passing through it than before, and then it does not purify water in the way that animal charcoal does.

Well, now some of the effects of sand filters, as employed by the Water Companies, Wanklyn points out. He says that the Thames water at Hampton contains fifteen parts of albuminoid ammonia, or ammonia derivable from organic matter, in one hundred millions, that is to say .15 in 100,000, which is the way we have generally reckoned it, and that after filtration by the company it only contains 5 or 6; so that you see water is capable of being purified—that is, the matters in solution are capable of being altered in drinking water on an immense scale.

Now what sort of things are these filter beds, as they are made, because laboratory experiments are all very well, but you have practically, to do it on a large scale. Mr. Hawkesley has made some large waterworks, as you are most of you probably aware, at Leicester, and there, there is a reservoir of forty acres in extent. There are also four filter beds, each ninety-nine feet long, and sixty-six feet wide, and eight feet eight inches deep from the ground. The water comes in separate channels to these filter beds, and it is passed downwards through the following filtering materials:—Two feet six inches of sand, and then two feet six inches of layers of gravel of various sizes (from the size of beans up to eggs) to the drains below and thence by pipes into an octagonal pure water tank. This tank, eight feet eight inches deep, holds seven feet eight inches of water, and is sixty-six feet from side to side. That is the general plan.

The supply comes to the filter beds from the reservoir at various points; it passes through two feet six inches of coarse sand—for, it must be observed, fine sand will not do, as it gets choked up by the suspended matters in the water—and then through two feet six inches of gravel. The filtering beds have sloping sides and are made of sand, fine gravel, coarse gravel, then very coarse gravel, with a drain at the bottom. The filtered water is delivered into an upright pipe in the tank, which comes within two feet of the top, so that the pressure of the water on the beds from above can never be greater than that due to a height of two feet. It is essential that the pressure on the surface of the beds should not be too great.

Well now from these filters six hundred or seven hundred gallons per day per square yard flow, and the proper rate of vertical descent for the water, as it is generally considered, is six inches per hour, not more, or sevent-five gallons per square foot in twenty-four hours, and that you see is about the rate at which it passes through these last named works; now the effect at this particular place is that the water is clarified, and a considerable proportion of the organic matters in solution are removed from it. The sand of the surface of the filter beds requires scraping from time to time and also renewing.

At the Gorbals Filtration Works near Glasgow, the filtering materials are placed in vertical compartments with passages between them, in each of which the water rises to nearly its original level and then flows over into the next compartment and down through the filtering material in it. There are two other plans I must mention, at Blackburn, for instance, there is no filtration. There they have a service reservoir, and they take the water out of it from the top by a sort of process of decantation. They let it settle, and then take only the water from the top. Another plan is in practice at St. Petersburg. There the water is made to fall down a series of

steps, and then through wire gauze, and lastly through sand filters, and by these means the water which is generally very impure is rendered tolerably pure and a considerable amount of putrescible organic matters are collected from this wire gauze.

Now we have to consider briefly the ways in which water may be distributed in towns. In the first place, as to the mains: their size must be calculated according to the supply required.

Mains are often made in towns on both sides of the streets in order that the supply may not be entirely cut off during repairs. There must be means provided by which the water may be stopped in a main in order that it may be repaired. The bends and junctions should always be curved. There should be no junctions made at right angles, and there should be no angular junctions if it can be helped. Mains should be made of cast iron. They should be greater than 3 inches in diameter. The best service pipes for houses are ¾ in., or 1 inch wrought iron service pipes that screw together. They are better than lead, and they are likewise cheaper than lead. Wrought iron pipes are better than lead for this reason, that certain kinds of water act upon lead. Soft water is apt to act upon lead. Fortunately, hard waters, containing a considerable amount of carbonic acid, act very little on leaden pipes, and so it is the practice very frequently to have leaden pipes and cisterns made of lead, and practically very little harm results. If you refer to the 25th Vol. of the "Proceedings of the Institution of Civil Engineers," you will find a discussion on water supply, and there you will see that Mr. Bateman gave it as his opinion that even soft water acted very little indeed on leaden pipes, after a time. It acts on them at first, but the leaden pipe or cistern soon gets covered inside with an insoluble coat of subcarbonate of lead, and the result is that afterwards the water acts very little on it. The water of Loch Katrine, which is supplied to Glasgow, acts very little on the leaden pipes and cisterns used. However, there is no reason for having lead if danger be apprehended as likely to result; wrought iron will do just as well and is cheaper.

A town may be supplied in one of two ways. These two ways are known as the Constant and Intermittent systems. First, there is the *Constant system*, in which, of course, the mains are always full and the water is brought into the houses by pipes from the mains, no cisterns being needed, as the water is always in the pipes, and you have only to turn a tap in order to get it. Secondly, there is the *Intermittent system*, in which the water is only supplied for a short time during the day, and in this Intermittent system it is therefore necessary to have cisterns in the houses. Now as to the relative advantages and disadvantages. Professor Rankine says: "The system called that of *Constant service* according to which all distributing pipes are kept charged with water at all times, is the best, not only for the convenience of the inhabitants, but also for the durability of the pipes and for the purity of the water; for pipes when alternately wet and dry tend to rust, and when emptied of water they are liable to collect rust, dust, coal gas and the effluvia of neighboring sewers, which are absorbed by the water on its re-admission. In order, however, that the system of Constant service may be carried out with efficiency and economy, it is necessary that the diameters of the pipes should be carefully adapted to their discharge and to the elevation of the district which they are to supply, and that the town should be sufficiently provided with town reservoirs. When these conditions are not fulfilled, it may be indispensable to practise the system of *Intermittent service*, especially as regards elevated districts, that is to say, to supply certain districts in succession during certain hours of the day." You see, therefore, that Professor Rankine emphatically condemns the system of Intermittent service as compared with that of Constant service.

Now the great objection to the system of Intermittent service is the necessity of having cisterns, whatever they are made of. Water becomes impure in cisterns, dust collects in them, and the cisterns require frequently to be cleansed. If this is not done the water may even become dangerous to drink. Where cisterns are necessary, slate cisterns are the best. They require to be made with

good cement, or they are apt to leak, and then you are liable to get red lead or something of that sort used to fill up the joints, and so you get the water tainted. Iron rusts, and for that reason cast-iron mains require to be varnished inside and out. Zinc has been used for cisterns and also for pipes, but zinc often contains lead, and cases have been known of lead-poisoning having resulted from the use of zinc pipes or cisterns. There have been plenty of ways proposed for coating lead pipes so that the water may not act upon them. Several of them are absolutely objectionable; one of the methods, for instance, was the use of a varnish containing arsenic; and even other varnishes which do not seem to be objectionable, are not now practically used.

If you look in Vols. 12 and 25 of the *Proceedings of the Institution of Civil Engineers*, you will see a great many arguments for and against both the "Constant" and "Intermittent" systems, and one argument against the "Intermittent" system is always that the amount of waste is enormous. It is stated as you will there find, that at that time the amount of water wasted in London was something like half the supply. You find it alleged that there is great waste also on the Constant system, because, it is said, the mains are always full and the taps are apt to be left running. But this may be provided against by having the taps placed inside the houses, and then you will be quite sure there is not much waste. Then, the waste that has been observed with the Constant system has been mostly caused where the Intermittent system has been changed for the Constant system, and in that case you do sustain a loss of water; a loss on account chiefly of faulty pipes, and leaky fittings, for such as may do very well under the Intermittent system are not good enough to be employed for the Constant system. In Liverpool, at a particular date, there were used 33,000,000 gallons of water a week, in the supply of which only 1,000,000 gallons were supplied on the Constant service, and the whole of the remaining 32,000,000 gallons were on the Intermittent service. For some weeks, as an experiment, three-sevenths of the town were put on the Constant service, and then the amount of water used rose from 33,000,000 to 41,000,000 gallons per week. But where there has originally been sufficient attention to the fittings, and where they are strong enough it is otherwise. For instance, in the case of Wolverhampton, at the same period, it is stated that in that town there was a saving effected by changing from the Intermittent to the Constant system, a saving of no less than 20 gallons per head per day. (Vol. xii., p. 503.)

A disadvantage of the Constant system is that the water supply sometimes runs short in the higher parts of the town, while in the lower parts there is a sufficient supply; so that cisterns would sometimes need to be provided, even under the Constant system, in these higher parts of the town.

As a summary: with the Constant system the waste of water is certainly less than with the other if the fittings are properly attended to, and if the fittings, pipes, &c., have been originally arranged for the Constant system. The water in the case of the Constant service is purer and fresher, and at a lower temperature in summer, and less subject to frost in winter. The water is purer because it escapes the impurities which I have already pointed out, as collecting in pipes, and it also escapes those impurities which the water gets by being stored in cisterns.

The inconvenience from interruption to the supply during repairs is never actually experienced, as the interruption need only be for a few hours. On the other hand, the interruptions and the waste caused by neglect of turncocks, by the limitation of the quantity of water, by leaky taps and cisterns, and in other ways—these inconveniences are absent. Then the leakage from pipes is less. In the Constant service the pipes are made stronger, and practically there is much less bursting. Mr. Hawkesley states that the difference between the systems is a question of pipes and fittings, and that when the supply is well managed the waste under the Constant system is less.

Then the water supply should always be to the top of the house, and if possible, to each story of the house. If cisterns are necessary those used for drinking water should always be separate from

any other cistern in the house, If, for instance, there is a cistern for the water closet, it should be entirely separate from the cistern used for the storage of drinking water; there should be two separate cisterns. Then a chief point to attend to with regard to the drinking water system is that it should be covered. Secondly—That it should be easily accessible, so as to be readily cleaned out: and thirdly—and this a most important point—that the waste pipe from it should empty out into the open air either over the surface of the yard or over a roof or into a rain water pipe, which itself does not go down into a drain. The waste pipe should on no consideration be connected with any water closet apparatus or with drains. This is almost invariably done, and that is why I insist so much on the importance of this point.

I may tell you that one of the most frequent causes of typhoid fever in London at this moment—of this I have not the slightest doubt—is that the waste pipes from the drinking water cisterns are connected with some part of the sewerage apparatus, and very often directly with the sewers. The house drain, more frequently than not, being unventilated, the waste pipe of the drinking water cistern, becomes the ventilator of the house drain, and the foul air of the house drain goes up into the space between the surface of the water and the lid of the cistern and is absorbed, and the result, in many cases, as I have frequently observed, has been a severe attack of diarrhœa through the whole household, or else of typhoid fever, and I have no doubt in some cases of cholera also.

The overflow pipes from other cisterns we need not be so particular about, because we do not require to drink the water; but it is just as well that they should empty in a similar way if possible. If not, they may be made to end in what is called the D trap of the water closet. I shall explain that, however, more fully further on.

Now we have brought the water into the house—either into the cisterns, or it may be, merely into the pipes, which are kept constantly full, and which have taps at various levels inside the house. When inside the house, it may be purified still further, if necessary, by household charcoal filters, or by boiling and then being left to stand in stone vessels. That is an excellent plan, and I must tell you here, that impure water may be purified to a very considerable extent by making an infusion in it: for instance, an infusion of tea. This is very important for you to know when you may have to drink water in marshy countries. A great deal of mischief is sometimes done by drinking water in marshy countries, and this mischief may be prevented by merely boiling it. That is a very good thing, but still it is better, on the whole, to make a weak infusion of something like tea, in it, and that is the system which has been practised for a thousand years in China.

MARITIME ATTACK BY TORPEDOES.

From "The Engineer."

Nearly at the close of the Crimean War, just twenty years ago, the first attempt at ironclad ships of war appeared before Kertch, in those floating iron boxes the Meteor and Thunder, built like the corresponding floating batteries of our allies, from designs suggested by the Emperor of the French, which latter were carried out under his naval constructors. These proved themselves invulnerable to 32 lb. round shot, at very short ranges; and there was not wanting on our parts some self-congratulation that our great iron-making country must derive from the discovery a new lease of our maritime supremacy. About the same time the first real achievements in the way of perfecting a system of heavy rifled artillery began to appear, by the adoption of ringed structure for guns in wrought iron or steel, and with these the prediction of Robins, that the nation that first produced an effective system of rifled fire-arms and artillery would—on land, at least, and for a time—out-distance all competitors in warfare, seemed about to

be realized. It has been realized, to a vast extent, upon land, and, together with the railway system, has permanently changed the former methods, tactical and strategic, of European warfare.

The idea of stopping a cannon shot by an iron plate probably never entered the sagacious brain of Robins—who lived in the pre-iron age ; nor could he have had any conception of the rapid and powerful progress of invention and mechanical power which characterize our epoch. From 1854 to the present hour the unforeseen contest of gun against plate has been uninterrupted ; though with little more recondite scientific base for the contest than the obvious fact that a thicker plate could still be pierced by a bigger gun than before ; and millions have been expended, and to a large extent wasted, in simply repeating upon a larger and larger scale this almost self-evident truth. From time to time scientific artillerists, engineers and naval constructors, have speculated upon whether the final victory would rest with the ponderous armor-clad, or the enormous artillery it was proposed to carry ; and, viewed from a scientific point alone, those were most nearly right who declared that the gun must be the final victor, by its almost limitless power of penetration or dislocation—the thickness of possible armor-plating being limited by the size of the ship to carry it not surpassing that which should be manageable in narrow waters, and in the perils of sea and weather. The stages at which the duel of plate and gun have arrived during the last few years have brought, in a more or less distinct form, before the minds of men regarding the subject with a larger view than that afforded by science only, that the contest at last, if carried on on previous principles, must draw near its close, and eventually be decided, not, perhaps, in favor of either plate or gun, but by the correlative conditions and financial or economic eventualities which the enormous increase in magnitude of both must give rise to.

The means of attack and of defence as they have been enlarged have inevitably led to our being compelled to put "too many eggs into one basket." We have come on the one side to armor of 2 feet thick, and costing probably for material alone in place £600 the square fathom, to say nothing of the cost of the ship to carry it, so that the destruction of a single iron-clad, carrying only a few ponderous guns, would involve a national loss in war material exceeding the value of many a naval squadron deemed powerful in Nelson's day. On the other hand we have arrived through the gradual stages of twelve, eighteen, twenty-five and thirty-five ton guns, at length at those of eighty tons, the first of which is now in progress at Woolwich. The actual outlay for the production of this first enormous gun, including new forges and forty-ton hammer, steam and hydraulic cranes, special furnaces, coil rolling and bending machinery, gigantic tongs of thirty tons weight, and a multitude of minor paraphernalia, will probably be little short of £100,000. If we assume that the gun itself shall ultimately prove a success—and in the hands of Colonel Campbell and Mr. Fraser we see no great reason to doubt this—then it would be unfair to charge the whole of this to the first gun, though nobody can predict what additional expenses in the way of plant the experience to be obtained hereafter from the first gun may suggest or necessitate. The estimated cost, however, for wages and material alone for the production, as stated on authority, of this first gun amounts to £6,500; and bearing in mind the margin which experience proves always exists between estimated and actual costs in all new and arduous engineering undertakings, we may safely assign from £10,000 to £12,000 as the cost of this single gun, and that with the ship that is to carry it, the gun-carriage, mechanical means of training and loading, and the many other paraphernalia that such a piece of artillery will entail before it is ready to be discharged against an enemy, the entire apparatus will stand in our national ledger at from £300,000 to perhaps half a million. Yet the very idea inseparable from these gigantic conceptions is that the chance of a single successful shot from either the attacking or attacked ship must in all probability disable or send her opponent to the bottom. Such is the swift catastrophe that seems inevitably attendant upon any real conflict at sea between the warships of our day. While we are at peace we can

look complacently at the enormous money stake thus set afloat in every iron-clad. We are amused by the newspaper accounts of the wonderful doings of a Devastation or some other terrible monster which, after a time, passes into oblivion, and as ten to fifteen millions must be annually spent upon the navy, we don't dwell much on the burden of these "fighting machines." But were the real blast of war to blow in our ears, and with worthy opponents such as may be discerned in the not distant future, the loss of ten or twenty of these costly monsters would simultaneously, or within a few months, command the attention of the nation in a very different way. No nation, not even one with the creative power and wealth of England, is rich enough to carry on a great war for any length of time upon a system which plays with half-million stakes upon the chances of a single cannon shot, and where the superiority won by courage, daring, and seamanship of former days is so much neutralized by mere mechanism, as is now the case, and must continue to be, while we continue the race of gun against plate. In the mean time it is one of the curious features of the case that science and invention have been hard at work upon methods of attack which, if successful, as some of them at least seem likely to be, must render absolutely nugatory all this ponderous armor as a means of defence and tremendous artillery for that of naval attack. With all the invulnerability of her sides, the bottom of the iron-clad is as defenceless against underwater explosion as is the belly of the poor crab against the tearing bill of the octopus. As a means of maritime defence the torpedo system has already proved itself powerful. The skilful barriers of moored torpedoes, by which Austria barred the entrance to Venice, were such as even British ships and crews would scarcely have dared to face, so certain and inevitable under almost all circumstances were these unseen means of destruction. At Pola, also, and in the American civil war, this means of defence proved correspondingly effective, but as a means of maritime *attack* the torpedo stands in a very different category. If we can only bring the explosive instrument into contact with the enemy's ship the result is pretty certain, but therein lies the difficulty; against the defensive torpedo, an enemy's ship or fleet must either keep aloof or run all the risks of a perhaps triple line of formidable and undiscoverable dangers; whilst as a means of attack there is added to the difficulties of directing a torpedo at all in any designed underwater transit, even against a fixed object, all those dodges and devices that vigilance and seamanship can suggest to enable the intended victim to evade the dreaded contact. We may here in passing direct the reader's attention to the critical and descriptive accounts to be found in our columns for the years 1867–68 of what had been achieved up to that period in the employment of torpedoes, both for defence and attack. The idea of an attacking torpedo is far from being a modern one. The "fire-ship" of Guianelli, the Italian engineer in the sixteenth century, of the city of Antwerp, was in reality a torpedo, which floated down with the tide and laid broadside on against the immense wooden bridge across the Scheldt, by which the Spaniards, under Parma, were steadily approaching the besieged city, was completely successful. Bushnell, an American engineer, very nearly succeeded in destroying a British frigate moored in American waters, by a torpedo brought to the ship and attached by the operator from his submarine boat, the torpedo being provided with a time lock.

About 1840, the well-known Captain Warner destroyed off Brighton a merchant ship placed at his disposal by what he called his invisible shell, which was in reality a torpedo drawn by a cord under the hull of the ship, and fired by the contact; but up to the advent of iron war shipping after the Crimean War little farther attention was given to this method of naval attack, the old system of cannonade, with the modern addition of firing live shells, which proved so tremendously destructive to the Turkish fleet at Sinope, proving more than sufficient for the destruction of any timber ship. Not long after the Crimean war a project was laid before our Admiralty for an attacking torpedo, consisting of a large shell suspended from the long bowsprit of the attacking ship, and so arranged that it could instantaneously be let go, and swing like a pendulum

against the quarter or side of an enemy's ship, on contact with which it exploded. A complete description of this early project exists in the archives of the Admiralty, and we shall probably be in a position at a future time to give its details and the name of the proposer. Several years afterwards very nearly the same idea was proposed to his own Government by the Russian Admiral Popoff, and is understood to have been adopted into that service. In this case, the pendulum shell was suspended from a derrick projecting to a considerable distance from the broad side of the ship, an arrangement in every respect inferior to the previous one, because it exposes the broadside of the attacking ship to the stroke of its own torpedo, with distance only to diminish the shock, in place of opposing to it her sharp bows, and also because a ship, discovered by the enemy's telescopes with the extraordinary appendage of a derrick projecting from her side, must create suspicion and be given a wide birth.

All such projects were at that period coldly received, and generally met with the request that they should remain in the Admiralty archives, and not be publicly mooted until a more convenient season. Since that time, and especially during the last ten years, a great deal of attention has been directed, though in a way so unobtrusive as to escape much public notice, by our naval and military authorities to experiments, upon the various contrivances brought to its notice by officers of either service, as well as by outside inventors. Amongst these, both in America and in England, were various projects for firing torpedoes, either from a large vessel like the Spuyten Duyvel, provided with an underwater tunnel, from out of which the torpedo was thrust, or by a torpedo fixed at the end of a boom or underwater bowsprit, carried by some description of small craft, and fired by contact, but neither of these projects could be feasibly applicable, except under very exceptional conditions, and thus the great problem remained open of some effective method of directing from a distance a torpedo which should come into contact with the hull of an enemy's ship and there explode. Among the more noticeable of these have been Harvey's torpedo, which floated forth from the attacking vessel at a known depth from the surface, is sent down upon the vessel to be attacked, whether by current or by its contained power, direction being given to it by its peculiar trapezoidal horizontal section, and by means of directing guy cords or wires. Whatever favorable results may have been stated to have been obtained with this machine, it is obvious that the means of direction must prove wholly ineffective if the distance between the ships be great, and any transverse current or wave action has to be encountered. The means of propulsion contained within the body of a torpedo is, like those for its direction, a matter of much difficulty. The relative density of the torpedo must be unaltered during its transit, for it must not alter its level beneath the surface of the water. Two concentric screw propellers, revolving in reverse directions, and actuated from within by compressed carbonic acid, or some other elastic vapor or gas, or by coiled-up metallic springs, or by electro-motive power, generated within the torpedo or in the attacking ship, and transmitted through an insulated wire, as in Way's, and one or more American inventions, have been among the mose promising methods of propulsion employed, but in all these the rate of transit through the water is not great, and the less that is, the less certain becomes the aim that can be taken at the ship to be struck.

Within the last year or two, experiments have been conducted at Woolwich upon a form of torpedo, the invention of Mr. Whitehead, an English engineer, for some time employed by the Austrians in experimenting upon torpedoes at the naval port of Pola, on the Adriatic. Mr. Whitehead's torpedo, with self-contained propulsive power, is stated to have been, in the judgment of the Austrian authorities, so successful as to have received a reward of £15,000. His invention was subsequently communicated by himself to our Government, and its merits sufficiently recognized—if we be rightly informed—by a large payment made to the inventor. It is also said to have been purchased by the American as well as by the French Government for large sums; so that Mr. Whitehead has already received a very ample reward for his invention. His torpedo consists of an

elongated metallic vessel, provided with projecting flanges or fins intended for securing its direction of motion only, the explosive agent being contained at the forward end, while the after end incloses a cavity into which air is compressed to a very high pressure (100 or more atmospheres), which thus requires a vessel of great thickness and strength. Much secrecy has been observed with respect to what is contained besides within the torpedo. The compressed air, however, is caused to act upon a double or concentric pair of right and left screw propellers by means of a little pair of air-engines; the torpedo is also provided with a rudder, which may be set to various angles so as to counteract lateral drift way, and it is stated or surmised that the obliquity of this rudder may be automatically altered in the event of the transverse current or other divellent force altering during the transit. This torpedo has been reported on by an American experimental commission, excerpts from which report will be found in *The Engineer*, vol. xxxvii., page 141. The enormous air pressures necessarily employed in this torpedo for even very moderate distances of transit form a great objection to its use, and already the experimental trials of it in this country have been attended with fatal results. Notwithstanding which, the rate of propulsion attained up to a very recent period does not appear to have reached more than about ten miles an hour, although, if the reports which have reached us be quite reliable, a speed largely exceeding this has been obtained at Woolwich in trials made in the Arsenal canal, in which a straight reach of considerable length exists. The greatest experimental distance of transit which limits the distance between the attacking and attacked ships does not as yet appear to have exceeded about 600ft., although the torpedo let loose in the water is capable of making a transit of about four-fifths of a mile, but no doubt with great uncertainty as to direction and reduction in speed.

If a velocity, as said to have been attained at Woolwich, approaching 30ft. per second, or even one a good deal less than that, has actually been attained, the submarine torpedo promises to become a really effective weapon of attack. Most of the experiments hitherto made with this class of torpedoes have been conducted at distances not exceeding 300 yards between the attacking and attacked ships, it being assumed that at that distance the attacking ship would be comparatively safe from the artillery of her opponent, the accuracy of aim decreasing rapidly with the distance through the movements of both ships, the smallness of the mark presented, and deviations in flight. Now, at the above rate, 300 yards of water would be run through in less than two minutes, and bearing in mind that every deviating force upon the torpedo due to wave or current action, and every disturbing influence arising from the movements of both ships, must be produced in proportion as the velocity of torpedo transit is greater, it would seem probable that here at length a reasonable chance is presented for striking the enemy's hull, and thus one prime difficulty of torpedo attack be overcome, though many others still remain to be surmounted. We are enabled to state, however, that in 1861–2, Mr. Charles Lancaster presented to our War Department designs and description for a torpedo which, like Whitehead's, contained its own means of propulsion. These designs were received and acknowledged with the request that they should be allowed by the inventor to repose in the archives of the War Department until some future necessity might arise for the employment of such a destructive mode of warfare, and so the matter did rest until a comparatively recent period, when, having heard of Mr. Whitehead's success, Mr. Lancaster called the attention of the authorities to his anticipation of the invention in 1861–62, or twelve or thirteen years since. From the nature of Mr. Lancaster's propulsive agent, a transit velocity equal at least to anything said so far to have been attained by Whitehead's and one that might be made greatly to exceed that of the latter, is physically possible, and would be attended with no danger to the operators. The torpedo itself might be much lighter, simpler, and less expensive both in construction and use, and if the splendid reward of £10,000 has been paid to Whitehead, it seems but hard lines that Lancaster should not be rewarded for his invention, which has been in the

hands of Government for twelve or thirteen years, and which offers some positive advantages over Whitehead's invention. There are two vulnerable places in every ironclad as yet constructed—the bottom and the deck—and whether the problem of attack by torpedo, and whether by Lancastre or by Whiting, be already solved, or on the way to solution, the attack by the vulnerable deck, remains an almost untouched subject for the inventive skill of the naval artillerist. A single very large shell lobbed in upon the upper deck and there exploded, would almost certainly put any ironclad *hors de combat*.

It was proved at Woolwich Marshes that a charge of only 10 lb. of powder sent a 36in. shell, weighing above a ton, a horizontal range of 360 yards, while with 20 lb. charge the range was increased to more than 900 yards, and with such small charges such shells might be fired from a mortar or howitzer weighing far less than an 18-ton gun. Probably spherical shells would not be the best for remaining where lodged upon a deck until the explosion took place, but the whole subject presents an excellent field for investigation, for the possibility of lodging a large shell, whether spherical or of some other form, upon an enemy's deck at such very short ranges can scarcely admit of debate, and if a ship of war may venture to approach another within 300 yards for the purpose of discharging a somewhat uncertain underwater torpedo, she may unquestionably do the same for the purpose of landing upon her opponent's deck a destructive shell, even though the latter be still subject to the possibility of missing its mark. Under circumstances otherwise alike, the attacking ship thus employed would have one element of safety which is scarcely possible if the attack be made by torpedo. The torpedo ship must arrest her course and become stationary before she can with any certainty launch her weapon ; the mortar ship, on the contrary, may keep on her way without her motion deranging sensibly that of the shell fired in the direction of her bows during its very short flight.

THE MARINE ENGINE OF TO-DAY.

From "Naval Science."

The more rapid decay of the boiler which has attended the comparatively slight increase of the pressure of the steam in the marine engine during the past few years presents a problem to the solution of which much attention is being paid, and probably, ere long, means will be found to remedy an evil which goes far to neutralize the gain in economy of fuel due tothe use of high-pressure steam. The mechanical difficulties to be met in the construction of a sectional marine boiler for extreme pressures appear already to have been, in a great measure, overcome, and no doubt perfectly trustworthy boilers of this kind can be made which will generate steam as efficiently as the boilers now in use, but advances in the direction of higher pressures must necessarily be slow in the case of the more important sea-going ships. Sufficient experience has, however, been gained with steam of from 60 to 80 lbs. pressure to enable the boilers now ordinarily in use at sea to be kept in fair order under the conditions to which they are subject in the majority of sea-going commercial ships, and for some time to come this must be regarded as the working pressure of ocean steamers.

The compound type of engine in general use at this pressure at the present time in the merchant service of this country, and adopted for the Royal Navy within the past few years, is one which, while possessing some evident advantages, also possesses serious defects ; and notwithstanding the risks which attend the trial of novel machinery on shipboard, attempts have been made on a considerable scale in the commercial marine to introduce simple expansive engines. With the exception of the North German Lloyd's Co., the steamship companies on this side of the Atlantic who have tried machinery of this kind do not appear to have met with any measure of

success, but in numbers of American steamers the simple expansive engine is used with most satisfactory results, and in a form which, to many English marine engineers, appears to be the most objectionable, a single cylinder and crank only being used. The relative merits of the two types of engine have formed the subject of much discussion in the technical press, and among the various engineering societies. We have ourselves devoted some space to the consideration of the subject, especially with reference to the use of the rival engines in ships-of-war, and the conclusions we arrived at were not favorable to the compound engine. The greater difficulty of rapidly handling, and the much greater liability to disablement, of this form of engine, its greater complication, and the larger space occupied by it in the ship as compared to the simple engine, renders its use in fighting ships specially objectionable. The objections to it in these respects apply in a minor degree to its application to commercial steamers,but they are sufficiently grave to warrant the use of the rival engine in many cases, even at a possible sacrifice in point of economy of fuel. What sacrifice would result, or whether any loss at all would occur, in the large engines of ocean steamers, is a matter upon which no absolutely decisive evidence at present exists, but, making use of such data as recent experience furnishes, we will endeavor in the present article to place the matter in such a form as to enable our engineering readers to arrive at a conclusion as to what are the probabilities in this respect.

The advisability has been suggested of introducing some more trustworthy system of trial, and proposed, for these runs, the registration of the weight of condensed steam discharged from the surface-condensers and jackets with the object of determining the efficiency of the steam in the engine. A trial of an engine of the compound marine type was made at Chatham Dockyard, last July, in this way. The particulars of this trial, which are of considerable interest, have just been published in the Prize Essay of the Junior Naval Professional Association,* together with the results of an important series of experiments recently made in the same way in America. For full particulars of these experiments and analyses of the results we must refer our readers to the Essay, confining ourselves to using the figures given so far only as they bear upon the points to which we wish to direct special attention.

When examined before the Committee on Admiralty Designs, in the early part of 1871, Mr. Reed strongly expressed an opinion that the economy stated to be due to the compound form of engine had been greatly exaggerated, and the evidence now accumulating confirms the opinion formed upon the imperfect data available at that time. Figures like 1.3 or 1.5 lbs. of fuel per indicated horse-power per hour have been constantly quoted for compound engines working at sea at pressures varying from 60 lbs. to 90 lbs. absolute at the outside, and, as engineers who have really studied the question are aware, a combination of the most impossibly favorable circumstances is required in order to attain such a result.

In the first place, the quantity of heat available for the performance of useful work in a steam engine is such that, in a condensing engine supplied with steam from an ordinary marine boiler evaporating 8 lbs. of water per lb. of fuel, the coal used could not be less than 1.15 lbs. per indicated horse-power per hour at 60 lbs. pressure absolute, presuming that all the ordinary causes of loss were eliminated. In order to obtain this result, losses from radiation, leakage, clearances, induced liquefaction, due to causes other than the performance of work during expansion, would require to be got rid of, and the expansion would have to be carried out to the lower limit of temperature, that of the condenser, taken in this case at 100° Fahrenheit. Under these circumstances the weight of steam theoretically required for pressures up to 120 lbs. absolute, as given by Professor Cotterill in his "Notes on the Theory of the Steam Engine," is as follows :

* "The Relative Merits of Simple and Compound Engines as Applied to Ships of War." Prize Essay. By Niel McDougall, Assoc. I. C. E., M. I. N. A., of the Department of the Controller of the Navy. (Griffin & Co., 15 Cockspur Street, Pall Mall, London, and 2 The Hard, Portsea, Portsmouth,)

Pressure in atmospheres.	No. of lbs. of steam required per horse-power per hour.
2	11.2
4	9.2
6	8.3
8	7.7

The accuracy of these figures can readily be demonstrated from the known properties of saturated steam, but the weight of steam actually required per H. P. for any given engine is a matter upon which but little trustworthy information is available. It is necessarily much in excess of the theoretical weight, bearing no definite relation to it. As a check upon the unhealthy spirit of emulation in the production of remarkable figures which the demand for economy of fuel has engendered, it is well, however, to keep the theoretical figures in view in considering the probable accuracy of results stated to have been obtained in actual practice.

It is to the loss from condensation in the cylinder that the difference between the theoretical and the actual weight of steam used expansively is in most engines chiefly due, and it is to the prevention of the losses from this source that improvement in the steam engine has been for some time in a great measure directed, although no definite knowledge of the extent of the loss traceable to condensation in the modern engine has existed. That it is actually greater, and that its effectual prevention in practice is more difficult than has been supposed by eminent authorities, appears to be evident from the most recent experiments. Professor Rankine appears to have regarded its prevention as a matter of no great difficulty, and to have considered that the extent to which expansion could be carried with useful effect should be determined from the back pressure in the cylinder and the resistance due to the friction of the engine, the terminal forward pressure of the steam for maximum efficiency being just sufficient to balance these two. In a paper on the "Economy of Power in Compound Marine Engines," submitted to the Committee on Admiralty Designs, he states :

"It is obvious that work continues to be done by the steam in driving the piston so long as the pressure behind the piston, or forward pressure, continues to be greater than the pressure in front, or back pressure, exerted by the steam which has already done its work, and which the piston is expelling from the cylinder; and hence it follows that in order to realize the greatest quantity of work which the steam is capable of performing the expansion ought to be carried on until the forward pressure of the steam behind the piston has fallen so low as to be just sufficient to overcome the back pressure ; and that to end the expansive working of the steam at an earlier period of the stroke is to throw away part of the power of the steam.

"This statement must, however, be taken with the qualification that when the excess of the forward pressure above the back pressure falls below the pressure which is just sufficient to overcome the friction, the work done is no longer partly useful and partly wasteful, but is wholly wasteful ; whence it follows that although, in order to obtain the greatest *indicated* work from a given weight of steam, the expansion should be continued until the forward pressure becomes just equal to the back pressure, the greatest *useful* work is obtained by making the expansion cease when the forward pressure is just equal to the back pressure added to a pressure equivalent to the friction of the engine."

And further :

"In order to realize the theoretical greatest efficiency in the expansive working of steam, the expansion ought to take place in a non-conducting cylinder, with a non-conducting piston. This condition cannot be absolutely realized in practice ; but means may be taken to diminish the loss of efficiency arising from the conducting power of the cylinder and piston until they become unimportant."

For the proportions of cylinder usual in compound marine engines the pressure per square inch required to overcome the friction in engines of good construction is such that the friction diagrams at the speeds at which they are usually taken become a mere line, and for all practical purposes the size of the low pressure cylinder might be determined on the supposition that the forward terminal pressure would correspond with the or-

dinary back pressure if the maximum efficiency of the steam were to be attained in the manner indicated by Professor Rankine. It appears to be evident, however, that the losses from the clearances and condensation at the higher grades of expansion affect the performance of the engine so seriously that the maximum efficiency of the steam is reached at a rate of expansion which places the terminal forward pressure much above that of the combined resistance of friction and back pressure, as will be plainly seen from the American experiments quoted further on. This remark applies to engines of both the compound and simple types, and before discussing the relative economy of the two kinds of engine it will help to form a just estimate if, in the first place, some idea can be given of the value to be attached to the remarkably good results in point of economy so frequently claimed for the compound engines now in ordinary use at sea.

The results of the trial at Chatham Dockyard, published in the Prize Essay of the Junior Naval Professional Association, are of considerable interest, as the engines are of the same type, but placed vertically, as those of the now well-known 'Briton' class. The engines are by the same makers as those of this ship, and are jacketed in the same way, the low pressure cylinder only being jacketed. The trial is the only one of a large compound engine of the marine type conducted in this country with which we are acquainted in which provision has been made to determine the efficiency of the engine apart from that of the boiler, and we here reprint the principal particulars, as they are also of special interest on this account :

TRIAL OF DOCK PUMPING-ENGINES H. M. DOCKYARD, CHATHAM, JULY 13TH, 1874.

Diameter of Cylinders	H. P. 43 ins., L. P. 75 ins.
Length of stroke	2 ft. 9 ins.
Mean pressure of steam in the boilers	53.5 lbs. per square inch.
Mean number of revolutions per minute*	87.6.
Mean pressure in cylinders	High 23.784, Low 5.993.
Indicated horse-power	High 505, Low 387—Total 892.
Duration of trial	3 hours 32½ minutes.
Description of coal used	Fothergill's Aberdare.
Quantity of coal used	12,320 lbs.
Quantity of coal used per I. H. P. per hour	3.74 lbs.
Water collected from hot-well	60,228 lbs.
Water collected from hot-well per I. H. P. per hour	18.42 lbs.
Water collected from steam-jacket	1,312 lbs.
Water collected from steam-jacket per I. H. P. per hour	0.401 lbs.
Water collected from steam-pipes	315 lbs.
Total quantity of water per I. H. P. per hour	18.922 lbs.
Quantity of coal burnt per square foot of fire-grate	17.8 lbs. per hour.
Velocity of piston, feet per minute	481.8.
Volume swept by piston per I.H.P. per minute, L.P. cylinder	16.57 cubic feet.
Volume swept by pistons per I. H. P. per minute....Total	22.03 cubic feet.

It is remarked in the Essay with regard to the results :

"It will be seen that the consumption of fuel determined in the same way as on the six hours' runs was found to be 3.74 lbs. per I. H. P. per hour. On a previous trial of 1¾ hours' duration, as a check upon which the present trial was ordered, the consumption of fuel had been calculated at 3.42 lbs. The steam is supplied from ordinary double-flued mill boilers, and upon subsequent evaporation trials of one of the boilers at atmospheric pressure it was found that the weight of water evaporated per lb. of fuel from 100° was 9.103 lbs. when burning 17.53 lbs. of fuel per square foot of grate per hour, the estimated rate of combustion, as will be seen above, on the trial, having been 17.8 lbs.

"As will also be seen, the total weight of steam or water, as measured, was 18.92 lbs. per I. H. P. per hour. This would give only 5.59 lbs. of water evaporated per lb. of fuel by the boiler, the lowest evaporative trial of which at atmospheric pressure gave 7.843 lbs. The coal used on all the trials was of first-

* The engines drive large centrifugal pumps, and the revolutions varied with the height of lift.

rate quality, and its evaporative power when tried in the marine test-boiler was found to be 9.635 lbs. of water from 100° per lb. of fuel.

"There are two things which are probable here—first, that the coal per H. P. as calculated is too high; and second, that the weight of steam per H. P., as measured, is too low. It would be impossible to fix accurately the weight of steam and fuel actually used, but making the liberal allowance of one-fourth, or 25 per cent., for error, we have 2.82 lbs. of coal per I. H. P. per hour as the probable consumption for an engine of the 'Briton' type, driven by ordinary Lancashire boilers, using the best Welsh coal, the probable rate of combustion being then only 13.35 lbs. per square foot of grate per hour, and if we assume that 8 lbs. of water were evaporated by the boiler per lb. of fuel, we have 22.56 lbs. of steam per I. H. P. per hour used by the engine."

These figures certainly form a remarkable contrast to the results of the lower power trials of the early high presssure compound engines tried in the Navy, and to the figures constantly given for the compound engines of the merchant service. An ordinary Cornish or Lancashire boiler at so low a rate of combustion as 13.35 lbs. of coal per square foot of grate might be expected to be nearly, if not quite, as economical as a cylindrical marine tubular boiler burning 20 lbs. per square foot of grate at sea. Looking, therefore, at the probable result of 2.82 lbs. of the Chatham trial, and keeping the theoretical consumption of 1.15 lbs. of fuel per H. P. in view, the value to be attached to such figures as 1.3 lbs. or 1.5 lbs., given for engines working as a rule with steam of about 45 lbs. or 50 lbs. supplied from boilers burning coal certainly not superior to Fothergill's Aberdare, may be judged of. Although, apparently, figures like these have been widely accepted as trustworthy, we have by no means been alone in expressing our doubts as to their accuracy. In a most interesting report by a board of American engineers to the Secretary of the United States Navy, published in 1874, the gain in economy by the use of the compound engine with 60 lbs. pressure, as compared to the simple engine of that Navy worked at 30 lbs. pressure, is calculated at 29.26 per cent., the weight of steam per horse power for the compound engine being determined as 22.46 lbs. The report states:

"The gain of 29.26 per centum in the cost of the indicated power is much less than that usually claimed for the compound engines by persons interested in their manufacture. If, as is often asserted, the indicated horse power is obtained at a cost of only two pounds of coal per hour, the boilers employed must evaporate 11.23 pounds of water per pound of coal. This quantity is much greater than has ever been evaporated by boilers of the types employed with the compound engines under consideration. The quantity of water evaporated in such boilers per pound of coal, at the high rates of combustion generally employed in English practice, will be found not to exceed eight pounds of water from a temperature of 100° Fahrenheit. When the apparent evaporation is greater the increase may be due to superheating the steam, the results of which practice may be equally advantageous in the case of engines of either type. The cost of the indicated horse power, then, in lbs. of coal per hour would be $\frac{22.46}{8} = 2.81$."

The coal trials conducted in the Royal Dockyards furnish ample evidence that the evaporation of 8 lbs. of water per pound of coal is a very good performance for a marine boiler under ordinary working conditions at sea, while from the recent American trials it appears to be probable that expansion is carried to too great an extent for economy in the generality of compound engines of English design. The best result given by the compound engine in these trials was attained by the 'Rush' with a ratio of expansion of 6.2, the volume swept by the piston of the low pressure cylinder being only 9.42 cubic feet per horse power per minute. The cylinders in this case were completely jacketed, and with a boiler evaporating 8 lbs. of water per pound of coal the consumption of fuel per H. P. per hour would be 2.3 lbs. The engine, as will be seen further on, was of small size, but a comparison of the result with that

of the Chatham engines is instructive, and, taken in conjunction with the result of the 'Bache' trials, it tends to show that the capacity of cylinder in engines of English design is unnecessarily large.

For engines of large size the figures given for the Admiralty six hours' runs are probably the most trustworthy yet available, as the coal used on all occasions is of practically the same quality from the best Welsh beds. Referring to the table below, it will be seen that the four last trials of the compound engines do not differ materially, and a mean of the five trials gives 2.4 lbs. of the best Welsh coal used per horse power per hour. This is below the probable result of the Chatham trial, but comparing it with the results given by five simple low pressure engines a gain of 18 per cent. by the use of the compound high pressure engine is shown. To obtain this result the capacity of the cylinder has been increased 50 per cent., and the pressure above the atmosphere has been doubled. The trials are all at full power, but it is pretty evident from the American experiments that the maximum expansion for economy had been reached in the compound engines, and that at lower power any further economy would simply be due to increased efficiency of the boiler.

Name of Vessel.		When tried.	Steam pressure; lbs. per sq. in. above atmosphere.	I. H, P.	Volume swept per I. H. P. per min. by piston.		Coal used per I. H. P. per hour.
					Cubic feet.		lbs.
Single engines.	Monarch	1869	25 lbs. to 30 lbs.	7470	11.8		2.79
	*Devastation	1873		5652	11.64		2.928
	Hercules	1869		7187	12.5		2.811
	Sultan	1871		8778	11.19		3.109
	Druid	1871		2038	12.6		3.001
					L. P. cylinder.	Total.	
Compound engines.	Briton	1870	55 lbs. to 60 lbs.	2019	13.4	17.8	1.981
	Thetis	1872		2036	13.6	18.0	2.545
	Thetis	1873		2000	—	—	2.600
	Amethyst	1873		1990	14.7	19.6	2.463
	Encounter	1873		2030	14.5	19.4	2.425

There can be no doubt that in some minds the belief in the efficacy of passing steam through a succession of cylinders amounts to little short of a superstition, and in such cases the important inferences to be drawn from figures like those given above are lost sight of. The fact is overlooked or forgotten that it was not until the compound engine was worked at higher pressure than the engines it has superseded that its superior economy could be distinguished at sea; that on land low pressure compound engines have been superseded wholesale by high pressure simple expansive engines; that there is abundant evidence that an increase in the pressure of the steam is followed by increased economy in the simple as in the compound engine, and that, therefore, on the broadest possible grounds, it might be expected that with equal steam pressure the difference between the performance of the two engines, as shown above, would be largely reduced, if it did not entirely disappear.

The experiments with the engines of the 'Dexter' furnish direct evidence of the economy which results from the use of higher steam pressure in the simple engine. Taking trials Nos. 3 and 7 for comparison, it will be seen below that in the same engine the horse power cost $20\frac{3}{4}$ per cent. more at 40 lbs. pressure than at 70:

* Twin Screws.

No. of trial	3	7
Mean boiler pressure above atmosphere lbs	68.70	40.625
Indicated H. P.	185.872	124.267
Weight of water used per I. H. P. lbs	23.8572	28.802
Ratio of expansion	4.557	3.337

This was in a completely clothed but unjacketed cylinder.

The very different results which may be obtained from steam of the same pressure in different engines of the same type is very clearly shown by comparing the results of the trial of the American steamer 'Mackinaw' (tried by Mr. Isherwood in 1864) with those given by the engines of the 'Dallas,' recently tried.

'MACKINAW.' SATURATED STEAM.

Diameter of cylinder .... 58 ins.
Length of stroke .... 8 ft. 9 in.
$\frac{\text{Clearances}}{\text{Effective capacity of cylinder}}$ 0.84

Ratio of expansion	1.38	1.68	2.33	3.68
Cut-off	.70	.56	.38	.21
Boiler pressure above atmosphere lbs	27	28	35	38
Absolute initial pressure in cylinder lbs	41.32	43.0	49.0	53.0
Feed water used per I.H.P. per hour lbs	32.913	30.628	30.31	36.04
Proportion of feed water accounted for by the indicator	.9254	.8857	.7818	.6218
Revolutions per minute	67.79	68.69	66.28	56.09

'DALLAS.' SATURATED STEAM.

Diameter of cylinder .... 36 inches.
Length of stroke .... 30 inches.
$\frac{\text{Clearances}}{\text{Effective capacity of cylinder}}$ .... 0.0802.

Ratio of expansion	2.317	2.935	3.893	5.067
Cut-off	.385	.287	.197	.132
Boiler pressure above atmosphere lbs	27.4	33.7	35.28	35.40
Absolute initial pressure in cylinder lbs	39.43	45.86	47.04	46.90
Feed water used per I. H. P. per hour lbs	30.99	28.90	26.96	26.68
Proportion of feed water accounted for by the indicator	.7348	.7337	.7687	.7195
No. of revolutions per minute	63.46	64.48	56.92	48.68

The ratio of clearances to effective capacity of cylinder was practically the same in the two cases, and under like conditions in other respects the larger engine might be expected to be the more economical. That the loss in the 'Mackinaw' was directly due to liquefaction is evident from the fact that the proportion of steam accounted for by the indicator gradually decreased at the higher grades of expansion, the proportion liquefied in the 'Dallas' remaining practically constant at all grades. It was also found in the 'Mackinaw' that on superheating the steam to such an extent that the indicator showed approximately the same weight of steam as actually used (the weight being calculated from the diagrams on the assumption that the volume indicated was that of saturated steam), the steam used per indicated H. P. fell considerably below that required for the 'Dallas,' using saturated steam, the figures being as under :

'MACKINAW.' SUPERHEATED STEAM.

Cast-off	.65	.23
Boiler pressure above atmosphere ... lbs.	38	39
Absolute initial pressure in cylinder ... lbs.	43.97	52.0
Feed water used per I. H. P. per hour ... lbs.	24.59	22.725

The cylinder of the 'Mackinaw,' like those of the other engines tried by Mr. Isherwood, was unjacketed and only partially covered with felt, the ends and slide-casing being unprotected. The cylinder of the 'Dallas,' on the other hand, was thoroughly protected, but the superior economy of this engine with saturated steam must have been mainly due to its greater speed. Although on account of its smaller size two square feet of condensing surface were presented in the cylinder of the 'Dallas' for every cubic foot of steam room, against one square foot in the 'Mackinaw," yet the time occupied in making a stroke was only one-ninth of that taken by the piston of the larger engine. In the absence of information as to the relative dryness of the steam used in the two engines, it is of course impossible to attach an exact value to the influence of the greater speed in presenting liquefaction, but the trials of these two ships may fairly be taken as showing the importance of high speed as an element of economy at the higher grades of expansion in unjacketed cylinders.

Whether the speed of the piston can be increased to such an extent in practice as to render the jacket superfluous is a question upon which it is impossible to speak with any degree of certainty. Judging from experience with the locomotive, using steam almost invariably super-saturated, it appears to be possible that this is the case. With saturated steam used expansively at ordinary speeds of piston, however, the jacket is essential to economy, and the recent American experiments show this plainly, although they also appear to show that its influence is not sufficient to admit of expansion being carried out to any great extent with adequate gain in economy.

Tabulated in Table 1 are leading particulars of some of the recent trials, and in Figs. 1 and 2 are shown diagrams from the engines of the 'Rush.' The great difference between the results

Fig. 1.—U. S. REVENUE STEAMER 'RUSH.' HIGH-PRESSURE CYLINDER.
Scale of indicator, 40 lbs. per inch.

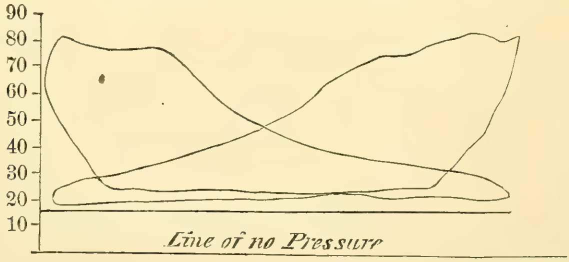


Fig. 2.—LOW-PRESSURE CYLINDER.
Scale of indicator, 16 lbs. per inch.

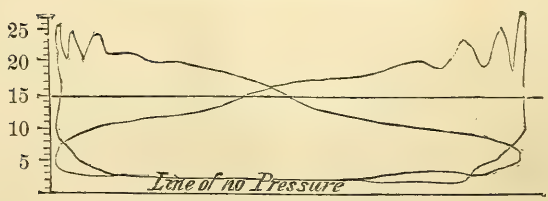


TABLE No. 1.

	Jacketed Cylinders.		Unjacketed Cylinders.		
	Rush compound engine.		High pressure.		Low pres.
	High Pressure.	Low Pressure.	Bach compound engine.	Dexter simple engine.	Dallas simple engine.
Number of trials for reference	1	2	2	5	12
Diameter of cylinder { High—ins... Low —ins...	24 38	24 38	15.98 25	26	36
Stroke of pistons.............ins...	27	27	24	36	30
Date of trial	Aug. 1874	Aug. 1874	May 1874	Aug. 1874	Aug. 1874
Duration of trial.............hours	55	6	2.06	34.5	31
Mean steam pressure in boiler...lbs.	69.06	36.73	80.28	67.12	31.96
Ratio of expansion................	6.21	4.03	6.65	3.48	3.13
Mean vacuum in condenser.....ins.	26.49	26.21	24.32	25.45	25.20
Mean number of revolutions per min.	70.84	55.47	47.69	61.06	61.51
Initial pressure in cylinder above atmosphere	H. P. 67.46 L. P. 8.65	35.44 7.18	76.33 2.45	64.40	31.85
Absolute initial pressure in cylinder..............................	H. P. 82.27 L. P. 23.46	50.24 21.98	91.05 17.15	79.20	46.58
Mean effective pressure........lbs.	H. P. 29.68 L. P. 12.72	18.88 12.29	43.51 9.75	37.53	23.52
Estimated friction pressure ...lbs.	H. P. 2.5 L. P. 1.5	2.5 1.5	0.75 2.25	3.0	2.5
Indicated horse-power	266.54	168.65	77.06	218.97	221.44
Effective horse-power..............	239.43	145.17	69.81	201.47	197.91
Steam per I. H. P. per hour.....lbs.	18.383	22.094	23.036	23.905	26.94
Steam per effective H.P. per hr. .lbs.	20.46	25.66	25.427	25.98	30.14
Coal per I.H.P. per hour.... (Calculated for evaporation of nine lbs. water per lb. of fuel.) lbs	2.042	2.455	2.559	2.656	2.993
Coal per effective H. P. per hour........ (Calculated for evaporation of nine lbs. water per lb. of fuel.) lbs	2.273	2.851	2.825	2.886	3.349
Ratio of L. P. to H. P. cylinder capacity..........................	2.25	2.25	2.5	—	—
Effective capacity of cylinder, cubic ft. per I. H. P. per minute...	H. P. 3.76 L. P. 9.42	4.65 11.65	3.46 8.44	6.17	9.81
Velocity of piston per minute....ft.	318.8	249.6	190.8	366.4	307.5

given by the jacketed and unjacketed compound engine will at once be seen, the unjacketed engine of the 'Bache' using as much steam per H. P. at 80 lbs. pressure as that of the completely jacketed engine of the 'Rush' at 37 lbs. How much of this difference was directly due to the jacket in this case is not evident, however. In Table 2 it will be seen that the compound engine of the 'Bache' was not so economical as that of the 'Rush,' even when using the jacket, and Mr. Emery suggests as an explanation, in his analysis of the experiments, that from the form of boiler the steam used in the cylinders of the 'Rush' might have been slightly superheated. The smaller size of cylinders, lower speed, and the fact that the large cylinder only was jacketed in the 'Bache,' all, probably, tended to a less economical result. Judging from the evidence of the indicator diagram, so far as it can be trusted, this type of compound engine, having one cylinder above the other, could hardly be expected in any case to be quite as economical as that of the 'Rush,' having two cylinders side by side with cranks at right angles. The most direct evidence of the utility of the jacket is, however, given by the trials of the 'Bache,' and here it will be found from trials No. 13 and 16 (Table 2) that the gain in the simple engine by the use

TABLE NO. 2.

Bache.

	Compound Jacketed.			Simple not Jack- eted.	Simple Jack- eted.	Com- pound not Jacketed
Number of trial for reference.....	7	8	9	13	16	3
Diameter of cylinder High—ins..	15.98	15.98	15.98	25	25	15.98
Diameter of cylinder Low —ins..	25	25	25			25
Stroke of pistons.............ins..	24	24	24	24	24	24
Date of trial.....................	May 12, 1874	May 14, 1874	May 15, 1874	May 18, 1874	May 18, 1874	May 14, 1874
Duration of trials..........hours.	1.983	7.066	15.233	2.05	2.116	2.133
Mean steam-pressure in boilers.lbs.	80.12	79.96	79.77	78.11	79.5	80.31
Ratio of expansion...............	5.732	5.707	5.097	5.32	5.11	5.634
Mean vacuum in condenser....ins.	26.56	26.11	24.39	24.22	25.52	24.656
Mean No. of revolutions per min..	56.34	55.29	53.62	47.07	53.84	49.265
Initial pressure in cylinder above atmosphere..................	75.41 8.66	H. P. 75.32 L. P. 8.96	74.47 7.52	72.75	76.1	73.00 3.9
Absolute initial pressure in cylinder.........................	90.30 23.55	H. P. 90.04 L. P. 23.68	88.78 22.83	87.39	90.74	87.72 18.62
Mean effective pressure......lbs.	42.93 15.88	H. P. 45.37 L. P. 13.96	43.06 14.908	32.328	36.94	45.137 11.2756
Estimated friction pressure..lbs.	0.75 2.25	H. P. 0.75 L. P. 2.25	0.75 2.25	2.25	2.25	0.75 2.25
Indicated horse-power...........	110.51	106.028	102.263	89.1	116	85.81
Effective horse-power.............	102.06	97.7	94.2	82.9	109.37	78.447
Steam per I. H. P. per hour....lbs.	20.3648	21.9661	22.3798	26.247	23.154	23.21
Steam per effective H.P. per hr.lbs.	21.9989	23.8385	24.287	28.21	24.56	25.3887
Coal per I.H.P. per hour.... (Calculated for evaporation of 9 lbs. water per lb. of fuel) lbs.	2.263	2.441	2.487	2.917	2.573	2.579
Coal per effective H.P. per hour........ (Calculated for evaporation of 9 lbs. water per lb. of fuel) lbs.	2.444	2.649	2.699	3.134	2.729	2.821
Effective capacity of cylinder, cubic ft. per I. H. P. per min..	2.8 6.9	H. P. 2.9 L. P. 7.1	2.9 7.1	7.2	6.3	3.0199 7.811
Velocity of piston per minute.....	225	222	214	188	215	197

of the jacket amounted to 11¾ per cent., the gain in the compound engine not being so much as this in the trials, the results of which are given in Table 2. But a comparison of other trials of the same compound engine (trials Nos. 2 and 6) shows the same gain as in the simple engine.

That increased economy is obtained by the use of steam of higher pressure in the simple engine is obvious, and the utility of the jacket, superheating, and high speed, as means of preventing loss from condensation, is also evident. The question, then, is, first, to which of the rival types of engine are these means of preventing waste most applicable in practice, and second, whether the compound engine when used under the conditions which experience has shown to be necessary for its satisfactory working is likely to be superior in economy at present pressures to the simple engine designed in accordance with the lessons which the limited experience with it have taught.

At pressure of 60 lbs. to 80 lbs. per square inch experience has shown that the superheater cannot be used with any degree of safety for the compound engine on account of the scoring of the cylinders and valve faces due to the high temperature and dryness of the steam. In the simple engine the lower mean temperature of the cylinder, as compared with the high pressure cylinder of the compound engine, would enable the superheater to be used with somewhat greater safety, but the valve faces would suffer in the same way in both cases, and, so far as we are aware, the superheater has not been used in any case with the

high pressure simple expansive engine at sea. With boilers having sufficient steam room to insure approximately dry saturated steam being supplied to the engine, it appears to be decidedly better to use the jacket in preference to the superheater in either type of engine. Here we find that in the compound engine with the high temperature maintained in the high pressure cylinder the use of the jacket on this cylinder has so frequently led to rapid wear, that in the practice of many engineers it has been abandoned on this account, and its use, where fitted, has been largely abandoned at sea. In some of the most successful compound engines the jacket on the low pressure cylinder has also been dispensed with, not, however, in this case on account of wear, but for the sake of simplicity, it being considered that any gain in economy which might be due to the jacket is not sufficient to counterbalance the additional cost and complication involved in the construction of an already sufficiently complex engine. It may be noted also that some of the experiments with the 'Bache' appear to bear out the supposition that with the steam but slightly expanded in each cylinder the use of the low pressure cylinder jacket is not attended by any marked advantage in engines of this type.

With the greater range of temperature of the cylinder of the simple engine, the effect of the jacket in inducing rapid wear could not be expected to be so great as in the high pressure cylinder of the compound engine, and there is nothing to show that any ill effects traceable to its use have been found at sea.

So little is known as to the value of high speed in preventing liquefaction in jacketed cylinders, that it is impossible to speak with any degree of accuracy with regard to it. The loss of pressure which takes place in the steam pipes and passages of high speed engines, and the importance of providing large passages, are, however, familiar to all engineers of experience, and there cannot be any doubt that the loss invariably shown in the combined diagrams of compound engines is due in a great measure to the resistance of the intermediate passages between the cylinders. It may safely be concluded, therefore, that any increased economy due to high speed is counterbalanced in a measure in the compound engine by increased loss between the cylinders.

So far as economy in actual working is concerned, it appears, therefore, that superheating or drying, wherever it can safely be resorted to, is quite as capable of application to the simple engine as to the compound; that the jacket can be used on the simple engine and on the low pressure cylinder of the compound engine, but that its use on the high pressure cylinder is objectionable, and that while increased economy may be expected from increased speed in both engines (and certainly so in the case of unjacketed cylinders), high speed is accompanied by an increase of the loss between the cylinders of the compound engine, the loss varying with the nature of the passages according to the form of engine.

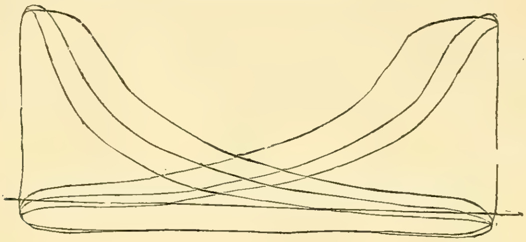
The most important lesson definitely taught by the American experiments is that which we have already indicated—namely, that expansion cannot be carried in jacketed cylinders with increased economy to so great an extent as has been supposed. In the simple engines tried, no provision against loss from the clearance spaces by cushioning in the exhaust was made, and the maximum efficiency of the steam was therefore reached at a lower grade of expansion than would have been the case had cushioning been provided for. The lowest consumption registered for the jacketed compound engine of the 'Bache' was obtained on the trial No. 7 (see Table 2), at the ratio of expansion 5.74, while in the simple jacketed engine the maximum efficiency appears to have been reached at the ratio 5.11 (trial No. 16, Table 2). As will be seen next page, the weight of steam used rapidly increased at the higher expansion in both types of engine, the loss being greatest in the simple engine and the unjacketed compound engine.

Referring to the diagrams from the 'Bache,' Fig. 3, it will be seen that the simple engine was worked at a disadvantage in the absence of cushioning, and this must necessarily have affected its performance to a considerable extent at the higher expansion. Taking the performances of the engines of both types as a whole, however, the soundness

BACHE.

	Simple Jacketed.		Compound.			
			Not Jacketed.		Jacketed.	
Ratio of expansion....	8.57	12.62	6.658	9.146	9.19	16.85
Weight of steam per effective horse-power......lbs.	26.23	29.99	25.427	26.285	22.81	28.698

Fig. 3.—'BACHE.' Simple Engine using Steam Jacket.
Scale of indicator, 60 lbs. per inch.



of the conclusion arrived at by Mr. Emery, the designer of the engines of the 'Rush,' that a greater ratio of expansion than from 4 to 5.3 at pressures of from 60 lbs. to 80 lbs. is unnecessary, appears to be evident. In long-stroke, well-jacketed engines in which the losses from the clearances are reduced, either by cushioning or by reducing the clearances to a minimum, as in the Corliss system, expansion with saturated steam can undoubtedly be carried to a greater extent than this with a positive gain in economy, and in drawing conclusions from these trials the small size of the engines must also be borne in mind. Comparing, however, their performance with that of the much larger Chatham engines, and with the results given for the six hours' runs, it is evident that the American engines were very economical, the result given by the engines of the 'Rush,' with a ratio of expansion of 6.21 only, being remarkably good. There cannot be any doubt that the economy shown here was due in a great measure to the fact that expansion had not been carried too far.

In the commercial marine it is to the ships of the mail service that the simple engine is most applicable. It is here that competition in speed of ship is keenest, that the danger of disablement of the machinery is most to be dreaded, and it is also here that saving of space is most important, and that intelligent handling of the machinery can be depended upon. Of the most successful of the great lines engaged in the most important and most rapid steam-ship traffic in the world, that across the Atlantic, the ships of the White Star Line may fairly be taken as foremost in point of speed. The builders of these ships, Messrs. Harland & Wolff, of Belfast, have taken the lead in the construction of the long ships specially fitted for this traffic, and in the choice of a compound engine they appear, as in other matters connected with their vessels, to have exercised a sound judgment. The compound engines of the ships of the White Star Line, as most of our engineering readers will be aware, are of the vertical inverted cylinder type, having two cranks at right angles and four cylinders, the high pressure cylinders being placed above the low pressure ones with the pistons connected to one rod. Although probably not quite so economical as the type of compound engine with cylinders side by side, this form of the compound engine possesses for the service to which it is applied in the White Star vessels many prominent advantages. The continually increasing

power applied to the Transatlantic steamers has led to a corresponding increase in the dimensions of the cylinders, culminating apparently in the engines of the 'City of Chester,' fitted by Messrs. Caird with two cylinders of 72 and 120 in. diameter. The stroke of these engines is 5 ft. 6 in., the cylinders being placed side by side with the cranks at right angles. The difficulties to which the great size of the cylinders of this type of engine have led are many. The difficulty of obtaining sound castings; the impossibility of efficiently balancing the enormous weight of the low pressure piston and gear, and of distributing equally, under all conditions, the power transmitted to the two cranks, has given rise to endless trouble in the breaking of pistons, the failure of crank-shafts, and other mishaps.

In large steamers of recent build, in which the form of compound engine with high and low pressure cylinders side by side is adhered to, the capacity of the low pressure cylinder has been divided between two cylinders, there being thus three cylinders ranged fore and aft in the ship. With a compound engine the space taken up in this way is objectionably large as compared with that required for engines of the type in use in the White Star Line. In these engines also the effort transmitted to each crank is approximately equal under all circumstances as to variation of power, while as compared to the large engines of the 'City of Chester' type, for which the three-cylinder compound engine is being substituted, they undoubtedly possess great advantages in point of facility of handling and in manageable dimensions of cylinders. Taking success in the hardest service to which a steam engine can well be put—that of driving a steamer at full speed, in all weathers, across the Atlantic—as a test of efficiency, we do not think that a better selection could be made for comparison with a simple engine than one of the compound engines of the White Star Line.

Designation of Engine.	A.	B.	C. (Britannic)
Length of stroke.......... feet.	7	5	5
No. of revolutions per minute.......... feet.	60	60	58
Initial pressure taken at.......... lbs.	60	60	60
No. of cylinders.......... lbs.	2	3	4 { 2 H. P. / 2 L. P.
Diameter of each cylinder.......... ins.	$62\frac{7}{8}$	$60\frac{3}{4}$	{ H. P. 48 / L. P. 83
Velocity of piston per minute.......... feet.	840	600	580
Distance of cranks apart.......... deg.	90	120	90
Maximum turning force on crank-pin (one engine).... tons.	71.8	67.2	75.7
Mean do. .... tons.	28.29	26.41	39.62
(a) Maximum twisting moment on crank-shaft (engines combined).......... foot-tons.	311.8	248	269
(b) Mean do. foot-tons.	198	198	205
Minimum do. foot-tons.	105	170.5	172.5
$\frac{a}{b}$..........	1.57	1.25	1.31
Volume swept by piston per I. H. P. per minute...... c. ft.	7.22	7.22	{ H. P. 2.9 / L. P. 8.7
Total capacity of cylinders, showing the relative space which they actually occupy in the ship.......... c. ft.	301	301	501

The engines are by various makers, but, taking the dimensions given for the engines of the 'Britannic,' recently engined by Messrs. Maudslay, we will endeavor to give an idea of the probable gain which might be expected to result from the adoption of simple engines in the Transatlantic steamers. In column C, in the table above, are given results calculated for the engines of the 'Britannic,' well known as being fitted with Mr. Harland's lifting screw. At about 58 revolutions per minute the engines develop their highest power of 5,000 horses, the volume swept by the pistons per H. P. per minute being then about

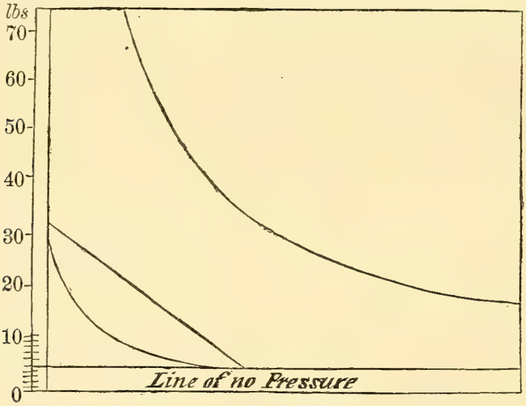
30 per cent. less than in the compound engines of the Royal Navy, particulars of which, when working at full power, have already been given. It will thus be understood that in selecting the engines of the 'Britannic,' we have taken a case in which one objectionable feature of the compound engine, that of a large cylinder capacity in proportion to the power developed, has been reduced to a minimum. We are not aware of any compound engine of large size in which the horse power has been produced with a less capacity of cylinder than in this ship.

In determining the capacity of cylinder for marine engines, the reduction of the pressure as the boilers become worn has to be kept in view, but for all practical purposes in the case we propose to consider this may be supposed to be provided for by basing the capacity of cylinder on the maximum horse power required, and on the maximum ratio of expansion which the recent experiments indicate as desirable.

Taking the ratio of expansion at 5, the clearances at one-fifteenth of the effective capacity, and making an allowance for cushioning, the volume swept by the piston per horse power per minute in the proposed simple engine would be 7.22 cubic feet, the indicator diagram being of the form shown in Fig. 4. Particulars of the engine are given in column A of the table. At 60 revolutions per minute the total effective cylinder capacity would then be 300 cubic feet in the simple engine for 5,000 H. P., against 500 cubic ft. in the compound, developing the same power at 58 revolutions. It will be seen that there is a gain here of 40 per cent. in capacity of cylinder as compared with the compound engine of minimum capacity.

FIG. 4.

Saturated steam in jacketed cylinder $pr. \frac{9}{10} = \text{const.}$



In engine A this cylinder capacity has been divided between two cylinders of 7 feet stroke, an arrangement which would give the greatest advantages in point of simplicity. A gain in length of engine room (about 4 feet) would be obtained here, and presuming no back guides to be fitted, there would also be a considerable gain in height. The stroke would be eighteen inches longer than that of the engines of the 'City of Chester,' the diameter of cylinder, however, being little more than half that of the low pressure cylinder of this ship. Keeping this in view, and also the fact that the speed is obtained with only 2 revolutions per minute more than that of the engines of the 'Britannic,' which have two pistons, one of 83 and one of 48 inches, acting on one crank, it will be seen that, as compared with English practice, the speed of 840 feet per minute is not alarming, while as compared with the piston speed of the long stroke American engines the rates is moderate. It must also be borne in mind that we are dealing in all cases with the maximum figures.

Considerable importance is frequently

attached to the fact that the variation in the turning force due to the variation of the steam pressure during expansion is not so great in the compound as in the simple engine, although in view of the results given by the single crank engines of Messrs. Holt's steamers and the American single cylinder engines, it is not clear upon what grounds objections on this score can be seriously urged. The difference between the two engines we are comparing in this respect will be best understood from a graphic illustration.

In Figs. 5 and 6 is shown the turning effort due to the pressure of the steam

SIMPLE ENGINE A. 2 CYLINDERS. WITH CRANKS AT RIGHT ANGLES.

FIG. 5.

Turning forces combined for a complete revolution.

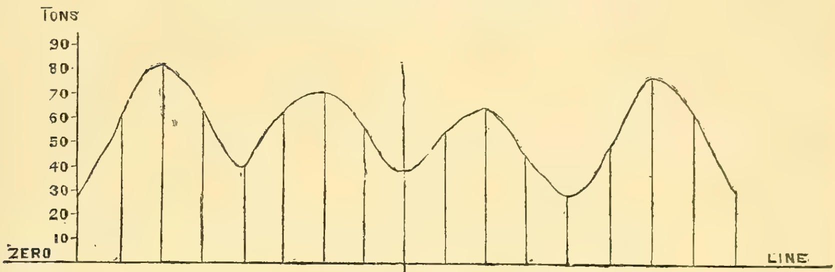
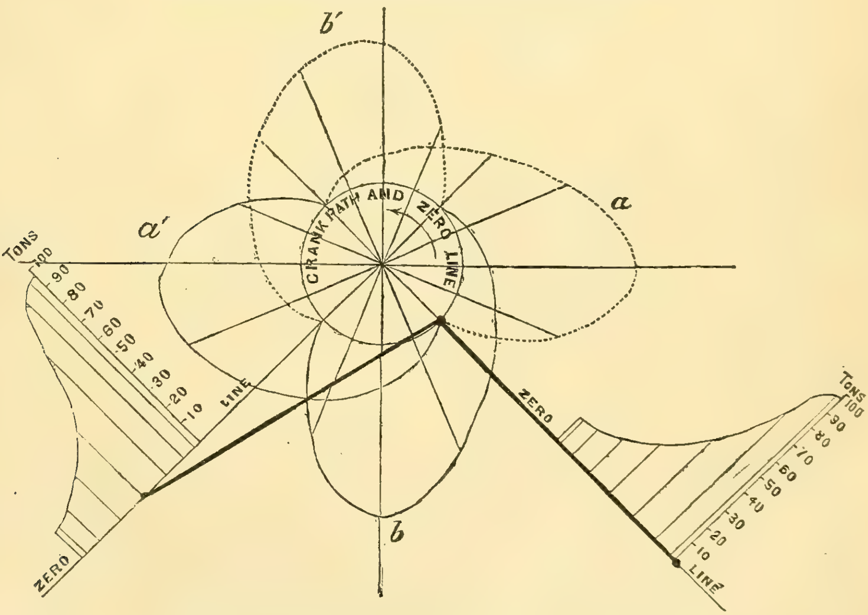


FIG 6

Turning forces on each crank-pin shown independently.



a and *b* forward strokes. *a′* and *b′* return strokes.

upon the crank pins of engine A for a complete revolution. In the lower diagram, Fig. 6, the turning effort on each crank is shown independently, and the pressure in tons upon the piston during a stroke is also shown. This diagram is arranged for the sake of clearances for an engine having the two cylinders placed at right angles, the effect being the same as if the cranks were placed at

right angles. For comparison diagrams arranged in the same way for engine C are shown in Figs. 7 and 8. The mean twisting moment on the crank shaft in the two engines is nearly the same, there being only the slight difference due

COMPOUND ENGINE C. 4 CYLINDERS. WITH 2 CRANKS AT RIGHT ANGLES.

FIG. 7.

Turning forces combined for a complete revolution.

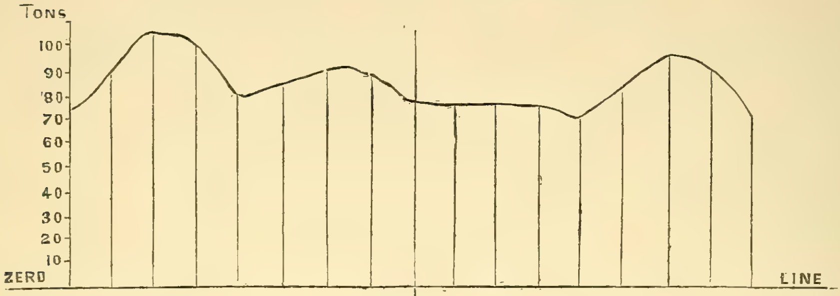
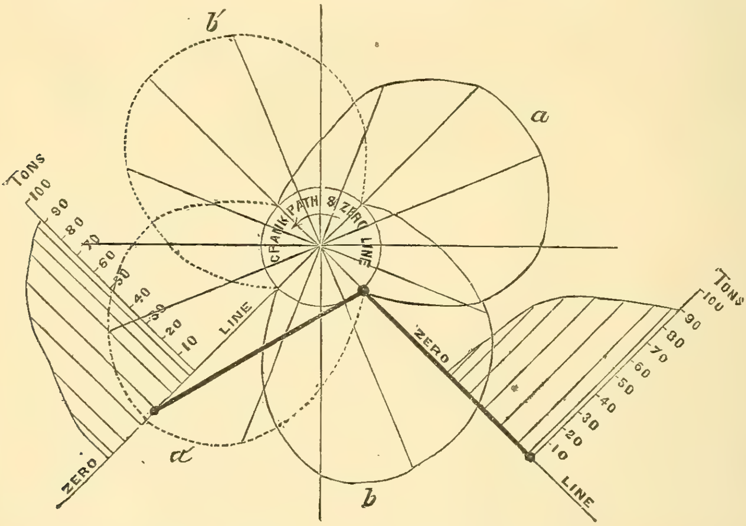


FIG. 8

Turning forces on each Crank-pin shown independently.



a and *b* forward strokes. *a'* and *b'* forward strokes.

to the difference of 2 per minute in the revolutions. On referring to the diagrams and table, however, it will be seen that the mean turning effort on the crank pin is only 28 tons in engine A against 40 tons in engine C. The *bete noire* of the engineer at sea, a hot bearing, is due, as a rule, when not occasioned by the use of improper materials or bad construction, simply to excess of pressure at the surfaces in contact. There is ample evidence in practice that bearings can be run at almost any speed without danger of heating if the pressure upon them be not too great. The friction of sliding surfaces, as a matter of fact, appears to decrease as the velocity increases.* "Friction diagrams" taken from marine engines at different speeds show an increase in the power required to

* This was shown to be the case in a number of experiments described in a paper by M. H. Bochet, an abstract of which appeared in the *Comptes Rendus* of the French Academy of Sciences for 1858. See Professor Rankine's *Machinery and Millwork*, p. 349.

drive the engine at the higher speeds, but the increased resistance shown is, no doubt, chiefly due to the increased power required to drive the pumps at the higher velocity.

An increase of the length of stroke not only reduces the turning effort on the crank pin, but it also reduces the direct thrust on the shaft bearings, and for engines of the same type the diminution of the loss from friction and tendency to heat the bearings may be taken as directly proportional to the increase in the length of stroke. It will be seen, however, from the diagrams, that, although the mean turning force is much less in engine A than in engine C, there is a greater irregularity in the force transmitted to the crank, and it might, therefore, be supposed that some loss from this cause might be found in practice. There is direct evidence, however, in the trials of the gunboats 'Swinger' and 'Goshawk,' which we have frequently quoted, that there is no loss of efficiency from this source. Diagrams from the 'Swinger,' fitted with simple engines, have been published in the Prize Essay of the Junior Naval Professional Association, and from them it is evident that the inequality in the turning force must have been considerably greater in this case than in engine A. Both on the measured mile trials, when tried at the same draught of water, and when the boats were run side by side, the results were slightly in favor of the engines of the 'Swinger." The six hours' run side by side may be taken as practically conclusive on this point, the displacement coefficients being 152 for the 'Swinger,' against 148 for the 'Goshawk.'

The comparison we have here made between a simple engine and a compound engine of type C is the more interesting as we have direct evidence in the American trials as to the relative economy of the two forms of engine. The engine of the 'Bache,' as already stated, has the high pressure cylinder on the top of the low as in type C, and the trials, particulars of which are given in Table No. 2, show that there was a positive gain in economy by using the low pressure cylinder as a simple engine when the jacket was used as compared with the compound engine not using the jacket. In comparing the two types of engine for absolute economy, it is evident that when the high pressure cylinder is dispensed with there is a reduction of the friction of the moving parts to the extent due to this cylinder, and that there is therefore a corresponding increase in the power available for useful work. The friction pressure for each cylinder was determined in the American trials, and the two forms of engine can therefore be compared in a rational manner by taking the weight of steam used per effective, or, as termed by the American engineers, "net" horse power, as a measure of their absolute economy. On referring to Table 2 it will be seen that the short trial No. 1 of the compound engine with the jacket shows a considerable gain by the use of the compound engine, but the accuracy of the results of this trial is not borne out by the figures given for the seven hours' trial, No. 8, at the same ratio of expansion, which shows a gain of only 3 per cent. by compound expansion. Some gain would certainly have resulted from cushioning in the simple engine, so that practically the same economy might have been expected from the two engines with the jacket in use in both cases, while there appears to be no room for doubt as to the actual superiority of the simple jacketed engine as compared to the unjacketed compound engine in the case of the 'Bache.'

From the various particulars we have given it will be seen that the performance of engines is affected so seriously by the initial condition of the steam used, by the speed of piston and by the proportion and size of the cylinders, that it is very difficult to arrive at a correct conclusion as to the real cause of different results being given by engines working under the same conditions as to boiler pressure and rate of expansion. A comparison of different engines must, therefore, always be a dubious one. In the case of the 'Bache,' however, we have the same cylinder supplied by steam from the same boiler and with the engine running at the same speed, the result being that given above. It is evident that the best that could be said in favor of the addition of the high pressure cylinder to this engine would be that it enabled the jacket to be in a measure dispensed with, and it need hardly be point-

ed out that a complete cylinder, with all its fittings, is rather an expensive substitute for an independent liner fitted in a simple cylinder.

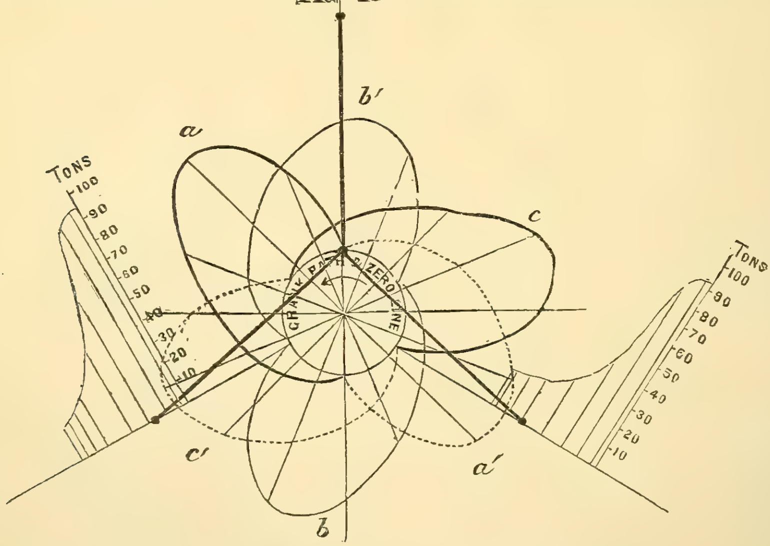
Taking the particulars we have given as a whole, the result of the comparison we have made can hardly be considered otherwise than as favorable to engine A, the only dubious points as compared with English practice being the increased length of stroke and the higher speed of piston. With the same capacity of cylinder as in engine A, however, a three cylinder simple engine could be made which, with the same length of stroke and speed of piston as in engine C, would be decidedly superior to this engine in regularity and balance of turning forces. Particulars of an engine of this kind are given in column B of the table, and crank effort diagrams are given under (Figs. 9 and 10).

Simple Engine B. 3 Cylinders. With Cranks at 120°.

Fig. 9.

Turning forces combined for a complete revolution.

FIG 10



a b c forward strokes. *a′ b′ c′* return strokes.

This is the form of high pressure simple expansive engine, the use of which is advocated for ships of war in the Prize Essay we have quoted from, special provision being proposed to be made for eadily disconnecting the cylinders at low speeds, or when disabled. In the more important ships of war the difficulty to be met with is, that on extraordinary occasions, as when chasing or being chased, a power of about six or seven times that ordinarily required

must be available, and it is essential that sufficient capacity of cylinder be given to insure economy in the engine itself at the highest power. It is then that waste from forced firing, and from generally decreased efficiency of the boiler, takes place, the enormous quantity of coal expended, and the comparatively small quantity which can be stowed in the ship, necessitating the utmost economy under these conditions. In working at the lowest powers with the large cylinder capacity thus necessarily provided, enormous loss from condensation takes place, and the only effective way out of the difficulty is to disconnect a part of the cylinder capacity entirely. The three cylinder form of engine, therefore, presents for this service many advantages, the American experiments rendering it evident that, with cylinders fitted to disconnect, such an engine would be more economical than a compound engine using the whole of the cylinder capacity (and with inter-dependent cylinders this is necessarily the case) at low speeds.

In the service to which our remarks have been directed, however, the range of power required under ordinary working conditions is slight, the ship being usually driven at nearly the full power the engine is capable of developing, and except in the case of larger powers than that of the present steamers, there appears to be no necessity for introducing a third cylinder. Keeping in view the results given by the American single cylinder engines and the engines of Messrs. Holt's steamers, it could hardly be expected that any gain of commercial value would be obtained by substituting, in the case we have considered, a three cylinder engine for engine A, with the the object of gaining greater efficiency of the mechanism.

We trust we have succeeded in placing prominently before our readers the fact that all the available evidence shows that practically equal results in point of economy of fuel may be obtained with either type of engine, when the same pressure of steam is used under the conditions we have chosen for illustration. Let this be understood, and the gain in space, weight, simplicity, facility of handling, the less liability to total break downs, and less first cost of the simple engine when intelligently designed be fairly realized, and shipowners on this side of the Atlantic will, no doubt, give it further trial. American experience shows that so far as wear of pistons and cylinders is concerned, jacketed engines of this type can be kept in perfect order, while the experience gained with the high pressure valve gear of the compound engine has enabled engineers to meet with confidence the difficulties arising from the increased pressure of the steam so far as it affects the wear of the valves. Difficulties of this kind, to which, together with unnecessary large cylinders, the unsatisfactory working of simple engines on this side of the Atlantic may be traced, are now being met on the largest scale by the eminent firm of Messrs. John Penn & Son, who have in hand for ships of war two sets of engines, amounting to an aggregate power of 10,000 horses. These are intended to work at their full power as simple expansive engines, and we have no doubt that other firms of equal enterprise are prepared to construct simple engines, specially fitted for the Transatlantic traffic, which, there is every probability, would be found to work with greater satisfaction to the engineers and shipowners than the cumbrous machinery now in general use.

Captain Eads has had compiled the following interesting and scientific data cencerning the Mississippi River, the work at whose mouth he has already begun: 1. Quantity of water discharged by the river annually, 14,883,360,636,880 cubic ft. 2. Quantity of sediment discharged annually, 28,188,083,892 cubic ft. 3. Area of the delta of the river, 13,000 square miles. 4. Depth of the delta, 1,056 ft. 5. The delta, therefore, contains 400,378,429,440,000 cubic feet, or 2,720 cubic miles. 6. It would require for the formation of one cubic mile of delta, five years and eighty-one days. 7. For the formation of one square mile, of the depth of 1,056 feet, one year and sixteen and 1-5 days. 8. For the formation of the delta, 14,268 4-5 years. 9. The Valley of the Mississippi from Cape Girardeau to the delta, is estimated to contain 16,000 square miles of 150 feet depth. It, therefore, contains 66,980,160,000,000 cubic feet or 454½ cubic miles.

ENGINEERING ON THE DANUBE.

From "The Building News."

For many years it has been debated among engineers whether the natural obstructions to the navigation of the Danube might not be, by the aid of science, removed. The obstacles were two—the one, however, closely associated with the other—a set of dangerous rocks, and a series of equally dangerious rapids. A project had long been matured, by a company of American speculators, to clear this important channel; but political considerations intervened, and a great European water-way was left in something like the condition of a half-choked canal. The reason was that, as usual, rival schemes were contemplated, as in the case of the Tiber, to which we lately referred. There was, for instance, the idea of a canal, to run parallel with the stream; there was the proposal to blast away a shelf of rocks forming the Orsova rapids; and there was also the suggestion of blowing up the Iron Gates, or granite bar, crossing the entire breadth of the river, and checking even the light Austrian Steamboats on their course. Here the water, as a rule, though its flow is wide, has a depth of no more than twenty inches, and the inconvenience to traffic of all kinds is enormous. The work, however, although decided upon so long ago as 1871, remains to be carried out in its entirety, when the celebrated Iron Gates will be no more, and Trajan's towing-path a mere memorial of antiquity. Now, the Danube, through its position in Europe, the extent of its available course, the importance and wealth of the territories traversed by it, should rank as the first river of Europe, a great facility for inland communication, and a grand link between the land and sea.

With the public influences which have hitherto established a sort of blockade upon its waters this present writing has nothing to do, the question for us being whether a generation that has canalized the Isthmus of Suez, and tunnelled the Alps, should allow the splendid border stream, as it may almost be termed, of the Continent, to be trammeled by a complication of geological embarrassments. It was thus, in an almost similar degree, at one period, with the Rhine. The Rhine had, naturally, no navigable outlets; it had no mouths; its only practicable way to the ocean was stopped by a bar, and it took a quintuple treaty to get rid of this obstruction. A convention of the same character set the Dunube free to the flags of all nations; but it did not blow up the rocks, or abolish the rapids. The Danube is, perhaps, regarded from a practical point of view, the most remarkable river in Europe. After cutting through the chalk mountains which stretch from north to south between the Balkan and Carpathian ranges, in a narrow channel where the waters boil, as if with impatience to escape, it widens like the Nile, intersects a valley nearly a hundred miles in breadth, passes under precipices on one side, and along marsh lands on the other, branches in every direction, forms clusters of islets, and then rebels against the Iron Gates. Two commissions of French and American engineers have reported that these are the main impediments to the utilizing of the river, which at its *embouchure*, gives soundings of fifty fathoms, on a bottom of shell and sand—a fact clearly proving that the Gates lock up, or largely obstruct, the possible trade of the interior. In spite of all this, not many years ago the accumulations at the entrances of the Danube absolutely closed them against vessels of even moderate tonnage; the mud and silt rose yard by yard in height; a few cyclopean rakes were idly employed in the attempt to remove them, and the Russian Government ordered a dredging machine, which, after having been worked for a very short time, was declared to be out of order, and has been laid up in ordinary ever since. But the scour of the stream, supposing the barriers farther up the valley removed, would have effected more than all the dredging engines ever manufactured. And what is the interest of the world in this grand artery of intercommunication,

concerning which the engineers are so busy just now? The Danube, which it is proposed, to unite by a canal with the Adriatic—although the proposed cost of the schemes has frightened even its projectors—begins its navigation at Ulm, an emporium of merchandise from France, Germany, and the banks of the Rhine. In its course it passes through the territories of four States, and receives the tribute of a hundred and twenty rivers. But the Iron Gates—the Porta Ferrea of the Romans—close the upper valley against all craft except the class of barges; and even these, when heavily laden, often find themselves stuck, most unwillingly, in rocky labyrinths, or on heaps of sand, even supposing them to have passed the thirty miles of broken rapid, which, it is now believed, may be blasted into a smoother bed. That such labor was, at one time, regarded as being among the Quixotisms of speculative science is shown by the gigantic expenditure and toil bestowed upon tunneling a carriage-way through the body of perpendicular rocks here overhanging the river—a work effected by gunpowder throughout, and quite equal in grandeur to the artificial road of the Simplon. But all modern enterprise, as yet, has failed to emulate the mighty monument of the Romans in that historic valley. Those Builders did not excavate; their tools and other appliances did not serve them adequately. They, therefore, constructed a covered gallery of wood along the face of the precipices, supported by strong buttresses, projecting over the stream, at the height of about six feet above its greatest altitude, and extending for a distance of nearly fifty miles. The holes for the reception of the horizontal buttresses on which the platform rested are as perfect now—as we have seen them—as they may be imagined to have been sixteen centuries ago; and, although the continuous line is occasionally interrupted by the dense masses of brushwood which have sprung up with the lapse of time, their course may be distinctly traced along the base of the mountains. In many places, indeed, a double set of holes may be observed, as if the lower ones had been constructed to receive brackets to aid in supporting the buttresses above. All antiquity notwithstanding, however, the principle importance in connection with every subject of the kind belongs to the present day; but it is especially interesting to note how, while awaiting the final triumph of engineering enterprise over the difficulties of the Danube, they have been lessened and mitigated for the sake of transit and commerce. The Austrian Danubian Steam Navigation Company, founded about forty years ago, and building and buying in the valley itself, though getting much of its machinery from Switzerland, works over three thousand miles of water, and keep five powerful dredging-machines, strangely enough, in constant employment. The operations forthwith to be undertaken will relieve them from this neccesity. They comprise a blasting and an embankment, and will be watched with curiosity from every quarter of Europe. It is believed that the cost of the works will be considerable less than that at which it was estimated by the American projectors, but they, it should be remembered, included in their design a lateral canal, with three approaches to the sea. The Commission of Austrian and Turkish engineers who, during the last two years, have been studying the problem on the spot, has not, indeed, reported in the most favorable terms; but their opinion, nevertheless, sanctions the idea, and suggests a plan for defraying the expense of developing it. That the Iron Gates are still practically shut is a reproach to the civilization of Europe; that they should remain so indefinitely seems impossible. England, at a far greater cost than is now threatened, cleared the important Paumban Pass, now the great water highway between Ceylon and the mainland of India, and sounded and measured every depth and shallow of the Red Sea. It would appear, then, to be a paradox now that a splendid river, such as the Danube is, should be closed against the higher necessities of trade and passage by a few bars of rock, and a few miles of rapids, which engineers declare may be blown out of the way without difficulty or danger. The Danube is to Europe what the Mississippi is to America—"the father of waters," and only requires a clear channel to become next in importance to a sea. Mechanical objections there are none to its perfect physical liberation.

ROTARY PUDDLING.

From "Engineering."

If we may judge from the interest manifested in the remarks made by Mr. Menelaus in his inaugural address to the members of the Iron and Steel Institute, and from the reports which reach us from the various ironmaking districts, the problem of mechanical puddling is now being regarded as of ever-increasing importance. Our own views on this subject are well known to our readers. We regard the present system of hand-puddling as a blot upon the progress which has been made in our iron manufacture, and as entirely inconsistent with the growth of our metallurgical processes. As we have pointed out on more than one occasion, the whole tendency of the modern development of our iron manufacture is towards the treatment of the material in large quantities, and with the aid of the least possible amount of hand labor; but the ordinary puddling process is totally opposed to this kind of development, the material being treated in small charges, and by the exertion of manual labor of the most severe kind. Considering these facts we think that everything tends to show that the puddling process of the future will be carried out in rotary furnaces capable of dealing with large charges, and worked in connection with plant capable of dealing easily with the enormous puddle balls thus produced, these balls being subsequently cut into pieces of convenient size and dealt with by existing machinery; and we believe that the time has arrived when our ironmasters should, as a body, consider this subject more earnestly than they hitherto have done. In making this last remark we have no desire to underrate the progress which has been already made; but this progress has been due rather to the energy of a few particular firms and individuals than any action taken by the iron trade as a whole, and it has thus been smaller than it need have been.

The only united action which has taken place has been that organized under the auspices of the Iron and Steel Institute—a body which, although the youngest of our important scientific societies, has set an excellent example to its seniors by its energy in promoting the industries it represents. As we pointed out on a recent occasion, the commission sent to the United States by the Iron and Steel Institute to examine into the working of the Danks furnace, has been attended with valuable results. It is true that, as regards the Danks furnace itself, the early anticipations set forth by the report of the commission have not been completely fulfilled; but this we regard as a small matter compared with the fact that English ironmasters have been familiarized with the results which can be obtained by rotary puddling, and that competent men, such as Siemens, Spencer, Crampton, and others, have been led to experiment further with that system of puddling, and to contribute towards making it a thorough success.

The process of mechanical puddling is essentially one requiring to be developed by experimental inquiry. To be commercially successful, machinery for puddling mechanically must not only be capable of turning out a product at least equal to that obtained by ordinary hand work, but it must also be enduring and be capable of being worked without "nursing" and without giving trouble from frequent breakdowns. It is this quality of endurance under the rough usage experienced in iron works which has proved so difficult to obtain in puddling machinery, and it is a quality the possession or non-possession of which in many instances, can only be determined by actual practice. We say in many instances—not in all—for there have been undoubtedly cases of the introduction into iron works of puddling machinery which would have been at once condemned at sight, had it come under the inspection, of a competent mechanic. Setting aside these exceptional cases, however, we may assume it to be an undoubted fact that the capabilities of puddling machinery can only be fairly tested by actual practical experience, and this being so the various failures of such machinery which have occurred, can only

be regarded as so many stepping-stones deposited on the road to success.

Thanks to these failures, indeed, and to the labors of those who have endeavoured to overcome them, we may say that at the present time mechanical puddling has been made a practical process, and has been brought to such a stage that its future development depends less upon individual exertion than upon its introduction into various iron-making districts and the consequent improvement of details of manipulation certain to result from more extended experience.

When the Danks furnace was first introduced into this country, it was in many quarters assumed—somewhat too hastily—that it was practically perfect, and the earlier experiences of Mr. Menelaus, Tooth, and others in the same field were temporarily forgotten. Practical trials, however, on a commercial scale developed more or less serious difficulties in the working and maintenance of the furnace, and from that time to the present constant efforts have been made to effect improvements. The present state of the matter as far as the Danks furnace is concerned is fairly set forth in the letter from Mr. Jones, of the Erimus Works, incorporated in the inaugural address of Mr. Menelaus, already referred to, and published by us the week before last. According to Mr. Jones the difficulty of the lining has been entirely overcome and "fettling can be procured suitable to any district," while he also speaks in hopeful terms of the means adopted to reduce the tendency to mechanical failures. As we pointed out a fortnight ago in our comments on Mr. Menelaus's address, the leading improvement introduced in the modified Danks furnaces at the Erimus Works—namely, the water-jacket arrangement—is one of the chief features in the Crampton furnace. We have no intention here of entering into any discussion relating to priority of design; but the fact of the Danks furnace being thus made to approximate in construction to the Crampton furnace as regards the mode of cooling by water irresistible suggests certain comparisons between the two systems of working, which in the present state of the puddling question are worthy of consideration.

As regards speed of working, there is probably nothing to choose between the two systems so long as both furnaces are in equally good condition; but in regular work the amount of the output from any given furnace is of course largely dependent upon the ease of maintenance of that furnace. As to what would be the relative endurance of two furnaces, each constructed on Mr. Crampton's plan with water-jacket arrangements, but one worked on the Danks system and the other with dust fuel, there are no data for actually determining; but there are certainly no reasons for believing that the results would be in favor of the former. With reference to this point we may remark that in the Crampton furnace the 5-in. cock revolving with the casing and through which the water supply enters the latter, is not liable to derangement, and has stood the test of long practical working, while this can scarcely be expected to be the case with the Danks furnace, as to effectively supply water to the latter involves the use of what may be regarded as a revolving cock 7 ft. in diameter, the wearing surfaces of which have thus a comparatively high speed. As regards quality of product, the difference, if any, may fairly be expected to be in favor of the Crampton furnace, on account of the high and uniform temperature which can be maintained and the regularity of the working—both matters which practice has shown to be of a vast importance. Taking, therefore, even the view of the question most favourable for the Danks system, we see no reasons why that system of working should, as regards quality or quantity of products, show any advantage over that of Mr. Crampton.

If now we consider the matter further, and examine the other qualifications which go to make up a successful rotary puddling furnace, we find that Mr. Cramptons's system possesses most important advantages. Thus, in the first place, the use of the dust fuel as carried out by Mr. Crampton gives a power of controlling the action of the furnace which is utterly unattainable so long as ordinary fires are used. We have frequently spoken upon this point, and the continued experience at Woolwich only serves to confirm all we have said. By shifting the handles regulating the sup-

plies of air and fuel, the temperature can be altered or flame made oxydizing or non-oxydizing at will, without a partical of coal getting into the iron, while by simply leaving the handles alone any given condition can be maintained for hours, if desired, absolutely without trouble. The ease and completeness with which the combustion of dust fuel can be controlled is, in fact, so striking that we are inclined to think that it can only be thoroughly appreciated by those who have examined it in operation, and who are, at the same time, conversant with the difficulties of managing ordinary fires. One result of the perfection of the combustion obtained with the dust fuel is the rapidity with which the furnace can be heated, the Woolwich furnace, when cold, having been repeatedly raised to a working heat in three-quarters of an hour with an expenditure of three and a half cwt. to four cwt. of fuel.

Another advantage of the Crampton system of working is that it does away with the construction and maintenance of all brick-built furnaces, and leaves the revolving furnace itself quite free at one end, the products of combustion returning through the same opening through which the jets of dust fuel are injected, and the furnace forming within itself a gas producing, gas consuming, and puddling chamber. We may remark, by-the-by, that during his earlier trials Mr. Crampton employed two chambers, but the alteration of the furnace so as to have one chamber only was found to save at least one-third of the fuel. Moreover, the Crampton furnace, instead of having two revolving joints to keep tight (to prevent the liquid iron from escaping), as in the case with Danks', has one only, while every facility is given for the expansion and contraction of the revolving furnace itself. All firebars, too, are done away with. These, we think, are mechanical advantages having no unimportant influence on the cost of maintenance, while as collateral advantages we have the effective utilization of slack coal and its combustion without the production of smoke. The fact of the fuel being conveyed to the Crampton furnaces by mechanical means, and all wheeling of coal to the furnaces being thus avoided, is also a feature of the system which should be borne in mind.

The Crampton furnace at Woolwich, after being in operation two years, was when we last saw it a few weeks since, in as perfect condition as when it left the boiler-maker's hands, it not even showing signs of distortion. During its working the liquid iron never issues from the revolving joints, while the friction is so small that the engines driving it require less than one-fourth the capacity of those found necessary on the Danks system. During the working of the furnace at Woolwich, there have been puddled, alone and mixed, large charges of Swedish charcoal iron, hematite, Northamptonshire, Derbyshire, South Yorkshire, and Cleveland irons, and judging from the exhaustive tests applied, the Cleveland pig has produced tin-plates, sheets, wire, rails, bars, and plates equal in quality to the products obtained from the best brands. Moreover, the steel made in pots and in the Siemens-Martin furnace from Cleveland puddled bars has proved equal to the best pot steel produced from Swedish charcoal iron. Most of these results were obtained during the time that the furnace was under the charge of independent manufactures who, after treating the puddled blooms in their own works, forwarded samples of their products to Mr. Crampton, who has thus been enabled to arrange at his offices at 4 Victoria Street, Westminster, a most remarkable and instructive collection of materials produced by mechanical puddling—a collection which is well worthy of examination by those interested in the subject.

Altogether when we consider the numerious advantages attendant upon the employment of fuel in the form of dust, and the general excellence of the mechanical arrangements which Mr. Crampton has designed and practically carried into effect for the utilization of such fuel, we cannot but regard the Crampton furnace as the most advanced solution of the problem of mechanical puddling, and we look forward with very considerable interest to the results which may be expected as soon as the Crampton furnaces now nearly completed in the Middlesbrough district are fairly at work; our interest being, we are sure,

shared by all concerned in our iron manufacture. It is anticipated that these results will be even superior to those already obtained at Woolwich, and from the completeness of the arrangements we have every hope that this anticipation may be realized.

REPORTS OF ENGINEERING SOCIETIES.

Master Mechanics' Association.—The following are the subjects for investigation and discussion the coming year, as reported by the Committee on Subjects, consisting of Reuben Wells, James M. Boon and John H. Flynn :

1. Locomotive Tests.
2. Best Material, Form and Proportion of Locomotive Boilers and Fire Boxes.
3. Locomotive Construction.
4. Locomotive Tire, Truck and Tender Wheels.
5. Best and Most Economical Metal for Locomotive and Tender Journal Bearings.
6. Is it Economical to use Injectors on Locomotives, and to what Extent ?
7. Boiler Explosions.

There were reports on the first four of these last year, but the subjects and committees were continued.

The following is the report of the Committee on Narrow and Broad Gauge Rolling Stock :

To the American Railway Master Mechanics' Association :

Gentlemen—Replies were received from twelve roads, and the information obtained is embodied in accompanying table. Very full reports were made by Mr. Peddle, of the St. Louis, Vandalia, Terre Haute & Indianapolis R., and Mr. Wells, of the Jeffersonville, Madison & Indianapolis R.

To the question, "From your experience, which is the best gauge, narrow or ordinary (4 ft. 8½ in.)?" Mr. Peddle replies as follows:

"From my experience I would prefer 5-feet gauge to either of the other gauges, for two reasons: The first is, that a wider wheel-base would enable the modern raised-deck coaches and sleeping cars, in which the centre of gravity is much higher than in the old-style coaches, to be run with greater steadiness and freedom from oscillation at high speeds. Another reason is, that it would give locomotive builders more room between the frames and enable them to lower the barrel of the boiler, and also widen the fire-box and do away with the off-set in the sides, in the vicinity of the tubes, a very objectionable feature, and make them straight or narrower at the top."

The information in relation to narrow gauges (viz., less than 4 ft. 8½ in.) is too meagre to make a fair comparison between them and the ordinary gauge.

From the table it will be seen that five prefer 4 ft. 8½ in. or 5 ft. to the narrow gauge or gauges. Two prefer gauges of 3 ft.

Wm. S. Hudson, }
H. G. Brooks, } Committee.
H. N. Sprague, }

—*Chicago Railway Review.*

IRON AND STEEL NOTES.

Carburation of Iron.—M. Boussingault has communicated the results of his experiments on the combinations of carbon, to the academy of sciences of Paris. M. Boussingault has found by most careful experiments that carbon exists in carburated iron in various proportions. Steel contains from 7 to 10 1000th parts when hard, and soft 10 to 15. Pig-iron contains 2 to 4 100ths, and sometimes 5 100ths. The quantity is difficult to settle, as it can only be ascertained in analysis by the difference with manganese, silicium, phosphorus, sulphur, and chromium. The average of the results is 4 4c. When gray the iron has given up its carbon in the form of graphite; but M. Boussingault found no sensible difference in the quantity of carbon in gray and white pig. In all cases, if the real combination of iron with carbon be admitted, it takes place thus—5 equivalents of iron for one of carbon. Whatever be the temperature it is impossible, says M. Boussinguault, to make more than 5 per cent. of carbon enter the iron ; this is the limit.—*Iron.*

Utilizing Furnace Slag.—Mr. W. Harold Smith, of this city, has been experimenting for some time with furnace slag, endeavoring to make from it a cheap and serviceable substitute for bricks and stone in paving and building. He has taken slag, from Robbins & Sons' Philadelphia Furnace, granulated as it came from the stack, then mixed it with two-thirds its weight of cement, subjected it to heavy pressure, and has succeeded in making firm, smooth, solid blocks, which have endured the following tests: They have been very highly compressed without crushing, were laid for pavement last fall and endured the winter's frost without damage, have been heated to a white heat and then thrown into water without disintegration, a 35-foot column of water was forced against one of the blocks without penetrating it, and they were found to endure heat which would melt an ordinary red brick.

Mr. Smith proposes to unite with any furnace owner in the manufacture of stones for flagging sidewalks, from 15 to 24 inches square and 3 inches thick, afterwards, as the demand improves, entering into the manufacture of other forms; or he will sell a furnace right at a reasonable figure. Mr. Smith claims that his stone, which he has named "Phœnix stone," can be made so cheaply and sold so readily that a furnace owner can make as much out of his slag as he can out of his iron. His address is 227 North Thirteenth Street, and his office is at 224 South Third Street, Philadelphia. He solicits correspondence, and invites attention to samples of "Phœnix stone" on exhibition at the office. We have seen these samples and believe they will make a good substitute for stone or brick. —*Bulletin.*

Belgian Competition in the Iron Trade. —Now there is so much talk of Belgian competition with our iron manufacturers, the following passages from the report of Sir H.

Barron, on the commerce, &c., of Belgium, just published among the reports of her Majesty's Secretaries of Legation, may be read with some interest. The competion, it would appear, must have arisen from the general depression in the iron trade first reaching Belgium, so that Belgian manufacturers were forced to great sacrifices to find a market of any kind. At any rate, Belgian trade has not been prosperous :—"On the whole," Sir H. Barron says, "the activity of all branches of trade in 1872 was rare and unparalleled. Above all, the trade connected with the manufacture and working of iron enjoyed an exceptional prosperity. All the smelting furnaces, iron works, rolling mills, machine works, foundries, and nail makers worked without intermission during the whole year. Many new factories were erected, many of the old ones were enlarged. At the same time the price of iron and its products rose. without a check from the beginning to the end of the year, to figures previously unknown. Pig-iron doubled in value during the twelve months. These prices left the producers good profits during the first six months. But the prices of labor and of coal rose to such exorbitant rates as to absorb finally the whole profits of the iron trade. Thus, the year which began so rich in promise ended in disappointment. The masters now find that they cannot tempt buyers at the present prices of iron, and cannot reduce those prices on account of the excessive cost of production. Many works have been closed and furnaces blown out in 1873, so that the trade is falling into a state of general stagnation. The present year will leave no profits to the iron-masters in general, save to such as possess colleries of their own, as, for instance, the monster establishments of Seraing, Couillet, Solessin, &c." Our trade, therefore, has not been suffering from the competition of prosperous Belgian ironmasters who were making a profit when our makers had none, but from manufacturers who were unable to get profitable orders.—*Iron.*

THE U. S. COMMISSION ON TESTING METALS. —The following circular has been recently issued:

The U. S. Commission on the Tests of Iron, Steel, and other Metals, proposes making a series of determinations of the effects of carbon, phosphorus, silicon, manganese, and other elements, upon the strength, toughness, elasticity, and other qualities of Iron and Steel. The specimens will be analyzed by the chemists attached to the Commission and subjected to tension, torsion, compression, and other mechanical tests. All experiments will be repeated often enough to reduce errors to their minima.

You would greatly aid the Commission, as well as the Iron Trade, by furnishing Iron and Steel bars, as follows:

Bars to be 7 ft. long and 1½ in. round.

Bars to be rolled, in case you have suitable rolls; if not, hammered billets, 3 in. square by 18 in. long, to be furnished in place of bars.

Bars to be stamped on one end with the initials of the maker, and the number of the heat or charge at which they were made; or, in case there is no such record, to be stamped with the initials of the maker and numbered on one end.

A full description of the kind and make of raw materials, and of processes employed in the manufacture of the bars, and also of the size of the ingot or pile, the number of reheats, and the extent to which hammering or rolling were employed in the reduction, to be kept in a reference book—each description having a number corresponding with that of the bar—would be of great value. Such a record is, therefore, particularly requested.

Your own analyses, including color carbon tests—in case you have made them—to be given in the above description.

Your mechanical tests of the material furnished, with statement of shape and dimensions of specimens tested, to be also recorded and furnished.

Please store the bars until the Commission informs you where to send them.

KIND OF IRON AND STEEL WANTED.

Any or all the following:

1	bar of	Steel,	containing......	0.10 %	carbon.
1	"	"	"	0.20	"
1	"	"	"	0.30	"
1	"	"	"	0.40	"
1	"	"	"	0.50	"
1	"	"	"	0.60	"
1	"	"	"	0.70	"
1	"	"	"	0.80	"
1	"	"	"	0.90	"
1	"	"	"	1.00	"

After selecting these bars by means of your carbon tests, please repeat the tests, so that there may be no error.

It is very important that the other elements should be uniform; therefore, these bars should be selected from charges made as far as possible from the same raw materials, and under similar conditions.

Also, please furnish—1 bar of each of such Irons or Steels as may show any particularly good or particularly bad qualities, or such as may exhibit any very marked or unusual characteristics.

1 bar of your best wrought Iron, with its trade mark stamped on.

1 bar of very hard, but not cold short wrought Iron.

1 bar of extremely soft wrought Iron.

1 bar of average "puddled Steel."

Any bars which you think may be usefully subjected to these tests—specially describing the materials and processes employed in making them, and their characteristics.

When the bars are tested, it is proposed to test a series in which the manganese varies by tenths of a per cent., other elements remaining the same, and another series for phosphorus, and so on.

Tool Steels will be tested in another series of experiments.

These determinations must, of course, require thousands of specimens, and be continued through a series of years. The final result must inevitably lead to a scientific syn-

thesis in the Iron and Steel manufacture, by which all required mechanical qualities can be accurately produced at pleasure.

A. L. Holley,
Chairman Committee on Chemical Research, and on Steels produced by modern processes.

RAILWAY NOTES.

Traction Engines on Roads.—The Larne traction engine nuisance case has occupied a great deal of time in its hearing, and a very considerable amount of our space. We do not say that either the time or the space was wasted; but we feel sure that even our good friends in the neighborhood of Larne must be gratified that the case has at last been concluded. The magistrates gave their decision yesterday. It was adverse to the plaintiffs, as the court held that a traction engine traversing the public road did not constitute a nuisance. Railways frequently ran close to public roads; and their engines might practically be regarded as forming a nuisance equally with traction engines, supposing these were nuisances; but railways run under Acts of Parliament and could not be prosecuted as nuisances. The magistrates held that traction engines also had the sanction of Parliament, and did not think that in this particular instance a nuisance had been proved. In particular, it was remarked that though the engine was regularly driven through the town of Larne, none of its inhabitants had come forward to complain of it. The charge was, therefore, dismissed; and we think there is substantial justice in the decision. It is no doubt very annoying to owners of horses to have them frightened on the public road; but the evidence on this point was not particularly strong, and without a very strong case indeed, the court would not have been justified in giving a judgment which would have had the effect of prohibiting the use of traction engines altogether.—*Northern Whig, Belfast.*

Boilers Lined with Copper.—An Austrian railway engineer has had the idea of protecting the boilers of locomotives against incrustation by means of copper plates. The front and back plates of the bottom of the boiler of an engine were covered with a sheet of copper 1 millimetre in thickness, the middle plate of the boiler being left unprotected. The engine was worked for two years on a portion of the line of the State railways where the water was of very bad quality. When the tubes were taken out the incrustation was found to be 10 millimetres in thickness on the surface of the iron, and only 2 to 3 millimetres thick on the copper plates. The iron was in many places corroded to the depth of $1\frac{1}{2}$ millimetres, while the copper was entirely unaffected, and the iron plate beneath it, when uncovered, looked perfectly new. The particles of incrustation were larger on the iron than on the copper. The cost of the copper covering is stated to be from 250 to 750 fr. per boiler. Another engineer, who examined and reported on the arrangement, says that the duration of the boilers is doubled or tripled by the application of the copper plates, which afford extraordinary security against explosion. The incrustation is much less on copper than on iron and steel, which is porous and slightly oxidized, and consequently the vaporization is more complete, and there is a corresponding saving of fuel. In the construction of a boiler to be lined with copper the iron plates may be of less thickness without risk; the weight of the boiler is thus considerably reduced, and, lastly, the expense for repairs is considerably diminished.

[This combination of copper and iron in iron ships has been found very injurious on account of the galvanic action between the two metals, and we would need more satisfactory experiments with water of different qualities, and particularly with the acid water common in coal mines before placing much value on this "improvement."]—*Engineering and Mining Journal.*

Steel Rails was the subject of a paper recently read before the Institution of Civil Engineers, London.

The object of this paper was to endeavor, briefly, to show that with care in manipulation and in selection of materials, Bessemer steel might be produced constant in quality, and that certain inexpensive tests might be applied which would absolutely determine the quality of the material, in most if not all of its characters, so far as was required for railway and structural purposes.

After an entensive experience in the manufacture of Bessemer steel rails, the author could only come to the conclusion, that the present system of inspection was highly unsatisfactory, and that, whilst it sacrificed a great number of rails, it gave anything but reliable results. The object appeared to be to test each individual rail in such a manner that its value should not be deteriorated. With this view many experiments had been made; and it was hoped that a system had been developed which, although primarily adopted for rails, might be made available for any other form of steel. The experiments appeared to prove that if it was possible to determine the hardness of the material, all the other properties might be calculated therefrom. If, therefore, the fish-plate holes in the rails were punched by a registering punching press, an index was obtained for the real quality of the steel. Experiments had shown that this force increased according to the thickness of the metal, in strictly arithmetical progression; for a hole $\frac{7}{8}$ in. in diameter the force required was about 8 tons per $\frac{1}{8}$ in.

Experiments had demonstrated that the zone of metal injured, by punching steel having a tensile strength up to 32 tons, did not exceed $\frac{3}{32}$ in. in breadth, and that if the fish-plate holes were first made with a small punch and then enlarged, by drilling to the required size, the steel was not more injured than if the hold had been drilled only. The Barrow Steel Company had shipped to Canada more than 100,000 tons of rails treated in this manner; and as there had been no case, to their knowledge, where rails had broken through

the fish-plate holes, they considered it a satisfactory proof that no danger need be feared. On the contrary, this mode of punching was one of the best practical tests of the quality of the steel; as, however hard (unless in an exceptional degree) it might be, the particular rails, if drilled, might be overlooked by the management; whilst if the steel had a greater tensile strength than 34 tons to 35 tons, the punch would break, when the rail would necessarily be rejected.

The results of experiments on rails, for the Furness Railway, also proved, that the punching strain was a true index of the steel as to its carbon percentage, tensile resistance, ductility, and the force required to give a permanent set. A fresh series of experiments on rails, which had been in use for several years on the same line of railway, proved that, contrary to what might have been anticipated, greater hardness had not conduced to the longevity of the rails, and that the softer ones showed the minimum of wear.

To sum up the experiments on Bessemer steel rails, it might be stated generally, that the most lengthened wear, under the heaviest traffic, did not appear in the slightest degree to deteriorate any portion of the rail, except the wearing surface to an inconsiderable depth. But this part of the rail, however hard and capable of resisting impact, lost almost the whole of its ductility, which was apparently due to the extreme molecular tension of the particles of the metal. If a worn double-headed rail was turned, though the new wearing table would be as strong as when first made, yet the total strength of the rail was materially lessened by the weak under-table, by which much of the elasticity of the rail was destroyed; though, by planing off a thin section, this, as had been demonstrated by experiment, could be entirely restored, allowing for a proportionate decrease in the weight of metal.

ENGINEERING STRUCTURES.

The Sewage of Paris.—The question of disposing of the sewage of Paris is constantly being discussed from one point of view or another. The municipal council received a report the other day from M. Desouches on the construction of a proposed sewer to connect the departmental collector of the Rue d'Allemagne with the great receptacle of night soil at La Villette, and thus allow of the sewage of the Pantin sewer, which now falls into the Seine at Saint Dennis, being carried on to the plain of Gennevilliers, where it may be employed in irrigation. M. Desouches recommended that the sewer should be constructed, but that the contents should be conducted to the plain in question only as an experiment, and after being diluted with at least five or six times its volume of the water of the Ourcq. It should be mentioned that the water of the Ourcq, brought to Paris by the canal which runs under the Place de la Bastille, is very impure water, only used for cleansing purposes. A member of the council said that recent discoveries had been made, which promised that the sewage might be purified sufficiently to be turned into the Seine without any inconveniences; but the council, knowing how little had in reality been effected in the way of artificial purification, and how costly all the processes are, passed over that part of the subject, discussed the general subject, and finally adopted the report. This will form an important link in the long chain of the application of the sewage of Paris, as the depot of La Villette is the receptacle of an immense quantity of night soil.—*Engineer.*

The Kansas City Bridge.—An absurd and injurious rumor appeared last week in an Atchison paper to the effect that the piers of the railway bridge at Kansas City are being undermined by the current, and that negotiations are making for a ferry boat for immediate use with which to transport the cars across the river. This would, indeed, be a misfortune, if true, for some forty trains cross the bridge daily, and it would be impossible to provide for their passage in any other way than by the construction of a new bridge.—There is, however, a certain basis, or occasion, for a rumor, exaggerated and false as it is. It has been "an open secret" that the pivot pier is partially undermined (on the north side, we believe) a fact known almost from the erection of the bridge, but not to an extent immediately impairing its stability. However it was deemed best to apply the ounce of preventive which is better than the pound of cure; and so, in December last, a thorough examination of the defective foundation was made by a submarine diver. It was found that a small portion, not exceeding one-twentieth of the whole, is defective, though there is no evidence that the break in the masonry has increased for some time. The examination was made by Mr. O. B. Gunn, who suggested a plan for repair, under which a contract was made in February last with the American Bridge Company of this city, which is now prosecuting it under the supervision of Major Gunn. The plan is that of a caisson to be built at the site of the pier and sunk around it; the intervening space being then relieved of water, the masonry will be restored beneath the pier, which will then be surrounded by a solid wall of masonry and caisson work, 11 feet thick, making it as secure and permanent as any pier on the Missouri River. When the contract was made, in February, as Major Gunn explains, it was too late to take advantage of the ice, and the unprecedented flood of April which has so delayed work upon the Atchison bridge, has prevented the repairs being made before this time. All the machinery, tools, timber, stone, etc., required are, however, delivered, and the caissons are framed, ready to be built and sunk around the pier as soon as the water is at a favorable stage, by the same men who have sunk the piers of the Atchison bridge, quicker and more successfully than any work of the same magnitude ever heretofore done in this country.—*Railway Review.*

ORDNANCE AND NAVAL.

The twentieth iron steamship launched from the yard of John Roach & Son since October, 1871, went into the water at Chester, Penn., on Saturday, 5th June. Her name is the "City of New York," and she was built for the Pacific Mail Steamship Company, being the second of their last order of three vessels now in different stages of completion. Each of these three ships is 353 feet long, by 40½ feet wide, with a depth of 39¼ feet from the hurricane deck and 31 feet from the spar deck. They will each be of a capacity of 3,500 tons, custom-house measurement, with accommodations for 153 first cabin and 1,200 steerage passengers.—*Bulletin.*

The trial trip of the Solimoes, a monitor recently launched by the Compagnie des Forges et Chantiers de la Mediterranée, was made a few weeks since. This vessel, which is built for the Brazilian Government, is a specimen of the latest improvements in naval architecture, gunnery, and engineering. The deck is only 90 cent. above water line, and hence has the appearance of a large raft 78 metres in length by 18 beam, with a draught of about 11ft. The cabins and engine-room are naturally below water line. She is propelled by a beautifully finished pair of engines of 550 nominal horse-power, but indicating 2000 horse-power. This vessel carries four Whitworth's guns weighing 25 tons each, mounted two to each turret. The weight of the projectiles is 275 kils., requiring a charge of 35 kils. of powder. These guns have given excellent results, and at a trial of their range carried a shot of 275 to a distance of 11 kils. (nearly 7 miles).

The Alexandra will be propelled by vertical compound twin-screw engines, which are to indicate not less than 8,000 horse-power. There are three cylinders to each set of engines, two low pressure cylinders of 90 in. diameter being placed on either side of the high-pressure cylinder, which is 70 in. in diameter, with a stroke of 4 ft. The surface condensers will have more than 14,000 solid drawn brass tubes, 7 ft 4 in. in length, and ⅝ of an inch outside diameter; the water for the condenser will be driven by means of centrifugal pumps worked by separate engines. To ensure perfect command when handling, separate starting engines are provided. To give proper ventilation for the stokeholes, ventilating engines and fans are fitted. Steam will be supplied by twelve boilers, placed in two stokeholes forward of the engines. The boilers are proved to 120 lb. to the square inch, but will be worked only to about 60 lb. The brass stern tubes, in connection with the screw propellers, are the largest and longest in the English navy. Each is cast in one piece, is 34 ft. in length, and weighs several tons.

Merchant Navies.—The *Magdeburg Gazette* publishes statistics showing that, although the German navy consists at present of only twenty-three vessels, with sixteen gunboats and six torpedo boats, the Mercantile Marine ranks next to those of England, America and France. It consists of 219 steamers of 165,178 tons, and 263 sailing ships of 1,143,810 tons. The former have increased since 1867 by nearly 50 and the latter by more than 20 per cent. It has nearly reached the strength of France, which has 316 steamers of 240,275 tons and 4951 sailing vessels of 906,705 tons, its tonnage having thus already exceeded that of the French Marine. England and its colonies have 4343 steamers of 1,641,000 tons and 32,461 sailing ships of 5,573,000 tons, while America has 3,625 steamers of 1,048,205 tons and 17,049 sailing ships of 2,146,585 tons. Next to Germany comes Russia with 185 steamers of 36,000 tons and 3089 sailing vessels of 771,292 tons. Austria has ninety-seven steamers of 52,005 tons and 2692 sailing vessels of 288,176 tons. Sweden has 406 steamers of 22,000 tons; Italy, 118 steamers of 37,810 tons, and as many as 19,488 sailing vessels of 1,031,907 tons; and Spain, 151 steamers, mostly colonial, of 45,514 tons and 4363 sailing ships of 345,186 tons. The merchant navy of Germany is manned by 90,000 sailors, while that of France has 96,000.—*Iron.*

The Vienna paper *Naval News* gives some information as to the present state of the Austro-Hungarian navy. The iron-clad fleet consists of four casemate ships, the Custozza, Lissa, Erzherzog Albrecht, and Kaiser, each with from fourteen to sixteen guns, engines from 800 to 1000 horse-power, and a tonnage of from 6000 to 7000. There are also 7 iron-clad frigates. The first-class, comprising the Erzherzog Ferdinand Max and the Hapsburg, have sixteen guns, engines of 800 horse power, and a tonnage of 5200 ; the second, consisting of the Kaiser Max, the Don Juan d'Austria, and the Prinz Eugen, are being converted into casemate ships; and the third, the Salamander and Drache, have fourteen guns, engines of 500 horse-power, and a tonnage of 3120. The unarmored fleet consists of three frigates, eight corvettes, five gunboats, one torpedo ship five schooners, two aviso steamers, two yachts, two Danube monitors, one factory ship, and ten training ships. The above shows that the number of ironclads has remained unchanged since 1872; of the unarmored ships, one gunboat and two steamers have been placed on the non-effective list, and two corvettes and two schooners have been added. The establishment of officers now consists of 1 admiral, 2 vice-admirals, 5 rear-admirals, 52 captains, 117 lieutenants, 145 ensigns, and 87 cadets. The number of seamen was increased in 1874 from 5702 to 5836, 3557 of whom on the average serve on board ship. The health of the navy is, on the whole satisfactory, and great progress has been made in the organization of the naval schools.

BOOK NOTICES.

Systems of Projectiles and Rifling, with Practical Suggestions for their Improvement, as embraced in a Report to the Chief of Ordnance. By Capt. John G. Butler, Ordnance Corps, United States Army. New York : D. Van Nostrand. Price $7.50.

For some years past Capt. John G. Butler, of the United States Ordnance Corps, has given unremitting attention to the improvement of projectiles, and rifled cannon, and he has now embodied the result of his investigation and experience, with the consent of the Chief of Ordnance, in a handsome volume, which will be of great utility to his brother officers, and of very general interest. In dealing with the question he arranges the different forms of rifling and projectiles under three general systems—the expansive, embracing all projectiles which in loading are inserted in the gun without respeect to the rifling, but which "take the grooves" by the action of the gases of discharge upon a device or feature of the projectile which is readily expanded thereby into the grooves of the gun; the compressive, embracing all projectiles which are loaded in a chamber, and then forced by the action of the powder through the bore of the gun, the diameter of which across the lands is less than the superior diameter of the projectile (all projectiles for breech-loading guns have heretofore been of this class); and the flanged system embracing all projectiles upon the cylindrical portions of which are projections which in loading are intended to be inserted into corresponding grooves in the bore of the gun. These projections may be studs or buttons, ribs or flanges, grooved shot being nothing more than flanged shot with wide flanges.

The simplicity of the expanding system, says Capt. Butler, strongly recommends it for muzzle-loading guns, and especially for field calibres, where rapid firing is a desideratum. Its advantages, indeed, are numerous and well acknowledged, but the defects of different projectiles of this class have been so many and serious as to more than counter-balance in the opinion of many the admitted advantages of the system. He proposes then a system of rifling and projectiles which removes these objections and defects. The rotating device consists of a double-lipped annular band or sabot attached to the base of the projectile. A narrow camelure between the upper and lower lips of the sabots distributes the gases of discharge so evenly that the slightest irregularity in the expansion of the upper lip has never been discovered; at the same time ballotting is almost entirely prevented. It is officially recorded that in the course of upwards of 100 rounds with the proposed projectile suoh a thing as a fluttering or in the slightest degree unsteady flight was never discovered. The upper lip of the grooved ring may be made so thin as to almost entirely check windage, and yet possess sufficient strength to rotate the heaviest shot. It may also be made so extremely thin as to close windage while the projectile is getting under way, but through sheer lack of stiffness ride over the lands towards the muzzle. The behavior of the new projectile is all that need be desired; it gives very superior accuracy, great steadiness and smoothness of flight, there was not a single case of stripping, though over 100 projectiles were fired, and not a single failure to take the grooves.

With regard to projectiles of large calibre and maximum weight, Capt. Butler does not deny that they might be benefited by a more substantial centreing, and he gives the diagram of a double centred shot, but it is found that his system is sufficiently accurate for all practical purposes. In discussing the compressive system he follows the same course, first points out and comments upon the principal defects, and then explains the methods of removing them. He adopts the same principle—the double-lipped annular sabot—as with muzzle loaders, and explains that there can be no undue strain from the checking of windage. The sabot is forced no more deeply into the grooves than occurs in a muzzle loading gun, while the slight quantity of gas which escapes is distributed evenly about the projectile. He mentions that if it be thought desirable in the use of either of the expansive projectiles described to entirely close the windage, this can be done very readily by a scft lead ring in front, or by a thin flange on the base of the projectile; and on the other hand, if windage is desired in the chamber as well as in the bore it can easily be effected by grooving the sabot by attaching it in segments, by grooving the chamber longitudinally with channels too narrow to admit of the sabot being forced into them, or by three or more holes running diagonally through the base of the projectile, and terminating at its cylindrical portion, but he considers the system better as it is.

Of course the practical value of a system can only be determined by actual experience, but it cannot be questioned that that advocated by Capt. John Butler is scientifically correct, since it secures accuracy of aim, perfect rotation with the least possible fatigue to the gun, owing to the reduction of friction to the minimum, absence of ballotting, and, probably also from the rotation being secured with so little friction between the gun and the projectile uniform and high velocitites. The projectile is so thoroughly strong that slight carelessness in manufacture or inferiority of materials do not seriously affect its value, whilst it can be roughly handled both in storing and transportation, is comparatively inexpensive, and does not injure the gun. Capt. Butler's book should be read by every officer of ordnance, to whatever country he may belong.—*London Mining Journal.*

Science Series. Skew Arches: Advantages and Disadvantages of Different Methods of Construction. By E. W. Hyde, C.E. New York: Van Nostrand. Price 50 cts.

The combination of strength, elegance, and economy in the designing and construction of a skew arch of more than limited span is a fair test of the ability of an engineer; and although when brick is the material used there is really little choice in the matter, it is probable that a more intimate acquaintance with the principles involved would lead to the adoption of stone in many cases where it is now neglected. To facilitate the acquisition of the requisite knowledge, the excellent little treatise of Mr. E. W. Hyde will be found very useful, since it contains the result of the author's careful personal investigation, chiefly with a view to ascertain the relative security and the

relative facility of construction, and descriptions of the manner of making the necessary draughts, templets, &c. To facilitate the systematic consideration of the subject he treats of the helicoidal, the logarithmic, and the corne de vache, or cow's horn methods separately, explaining that the first two named are derived from the nature of the coursing and heading joint surfaces and their intersections with the soffit, and the third from the soffit itself, which is a warped surface that has been thus named.

Commencing with the helicoidal method, he explains the mode of draughting the arch, and then investigates the security of an arch, constructed according to this method, remarking that in order that there may be no tendency in the successive courses to slide upon each other it is evident that the coursing joint surface must be at every point normal to the direction of the pressure at that point. It is probable that the direction of pressure varies somewhat with reference to the vertical plane in different portions of the arch, especially if the crown settles to any extent after removal of the centre. Still it must be approximately parallel to the plane to the face, otherwise portions would be left unsupported and fall. He assumes that it must be parallel, and then explains the nature of the curves, and the direction of their tangents at the point of piercing the soffit, subsequently giving an analytical investigation of the curves.

Similar information is then given with regard to the logarithmic, and the Corne de Vache methods, and the author then discusses the relative advantages of each. There is one advantage, he remarks, possessed by the helicoidal method over each of the others—it may be constructed of brick. This is owing to the fact that the successive coursing joint curves are parallel, so that the voussoirs, except those at the end of the courses, are all exactly alike, while in the other methods each stone is different from the next one, though the two halves of the arch on each side of the keystone are alike, so that any stone cut for one side will fit also in the corresponding place in the other side. The fact that the different voussoirs are alike in the helicoidal method of course lessons the labor of preparing the drawings, and of making the necessary measurements. As reregards the difficulty of cutting the stones, this method does not seem to have any serious advantage over the others even when the approximate method is adopted, while if the coursing and heading joint faces were cut with exactness as helicoids the difficulty would be fully equal if not greater than that by the other methods. It may be considered an advantage as regards appearance that the quoin stones should be all alike, or rather those faces of the quoin stones which coincide with the faces of the arch. This, of course, is the case only with the helicoidal method. He thinks, however, that the gradual decrease in the size of these faces from one side of the arch to the other would not be displeasing to the eye when taken in connection with the direction of the coursing joint curves, which would make the reason for the decrease obvious.

The real test, however, of the relative value of the different methods would appear to be that of security. When this test is applied the logarithmic and cow's horns methods both exceed by far the helicoidal. In the last-mentioned when semi-circular there is always a tendency to sliding on the coursing joints both above and below a certain point; that is, the assumed direction of pressure is nowhere normal to the coursing joint except at a certain height above the spring plane equal to r sin. $39° 32' 23''$, and that near the springing plane this tendency to sliding increases rapidly with the obliquity up to $a=20°$ (about); while in the logarithmic method along each coursing joint curve this tendency is zero—that is, the assumed direction of pressure is normal to the coursing joint surface in any of the coursing joint curves, and in the cow's horn the tendency is small as compared with the helicoidal. The logarithmic method, therefore, seems to approximate to theoretical perfection as regards security, is followed closely by the cow's horn, and at a great distance by the helicoidal. The cow's horn soffit admit of plane coursing joints, which are not feasible in the others, and thus possesses an advantage over them, if such an approximate construction be desirable. If cheapness be an important item to be considered, the last-mentioned method would seem to present most advantages, as avoiding almost entirely the use of curved surfaces, and at the same time reducing the sliding tendency to a small amount. If the main thing to be considered is security the logarithmic method must stand first.

From the manner in which Mr. Hyde has handled the subject, the reader will have no excuse for failing to comprehend it thoroughly, and whether he desires merely to understand the scientific bearing of the question, or to make the necessary drawings, patterns, &c., to apply his knowledge practically the volume, which is amply illustrated, will give him all the information he requires.—*London Mining Journal.*

MISCELLANEOUS.

The Steam Magnet.—M. Donato Tommasi states that, if a current of steam at a pressure of 5 to 6 atmospheres is passed through a copper tube of 0.08 to 0.12 inch in diameter, and coiled spirally around an iron cylinder, the latter is magnetized so effectually that an iron needle, placed at the distance of some inch or two from the steam magnet, is strongly attracted, and remains magnetic as long as the steam is allowed to pass through the copper tube.

Artificial Hardening of Sandstone.—Manfred Lewin has tried with success in his quarries at Saxonia, and at Neundorf, near Pirna, a process of impregnating sandstone. The stone there quarried is porous and readily absorbs water to a certain depth; it is this fact which renders it possible to introduce a solution to harden the surface. Lewin impregnates the stone with solutions of an alkaline silicate and of alumina; there is thus

formed an aluminum silicate within its pores, which gives to the surface considerable resistance. The solutions employed are made with soluble glass and with aluminum sulphate. After the impregnation, the sandstone may be polished like marble, which it then resembles closely. Heated to a high temperature, the exterior layer vitrifies and thus may be colored at pleasure. The coloration may even be obtained simply by mixing the desired pigment with one of the two solutions used for the impregnation.

Cleopatra's Needle.—The fine obelisk which goes by this name was offered to the British Government in 1820, by Mahomed Ali Pasha, but has never been removed owing to the difficulty of transit and also a report that it was much defaced towards the base. A short time since General Alexander wrote to say that he had gone to Alexandria for the purpose of examining the prostrate obelisk and had found it, with its hieroglyphic inscription in perfect preservation. On the authority of experts he asserts that its safe transport to England is quite practicable, and proposes that it should be erected on the Thames Embankment. General Alexander, on the same authority, states the cost at £10,000, for which he suggests a Parliamentary grant, observing that this is just an eighth part of the sum expended by the French Government in the transport and erection of the obelisk of the Place de la Concorde. There cannot be two opinions regarding the ornamental effect of this fine relic on the Embankment—a work itself in extent and strength worthy of ancient Egypt; and in the present state of engineering art there should be no difficulty in bringing it over and placing it.

White Brass Bearings.—In the case of bearings for shafts and axles the value of the metal alloy used can only be ascertained by actual practical experience, a circumstance which prevents many inventors of really useful alloys from even getting their material tested; it would seem, however that at the presant time this causes but little inconvenience, since the economy and durability of white brass really leaves nothing to be desired. Although somewhat similar in color, white brass, or as it is more commonly called Parsons' white brass, differs essentially from what is generally called white metals, and should not be classed with them, being harder, stronger, and sonorous; it is, in fact, as its name implies, a species of brass, and behaves like it under the tool when bored or turned, it does not clog the file, and is susceptible of a very high polish; at the same time, it fuses at a lower temperature than ordinary brass, and can be melted in an iron pot or ladle over an ordinary fire, which renders it exceedingly useful for fitting up engines and machines where first cost is an object, as it can be run into the plummer-blocks or framing to form the bearings, bushes, sockets, &c., without the expense of fitting or boring them, or it can be cast in metal moulds, or, like ordinary brass or gun metal, in sand or loam. It has now been in use for many years for railway carriage and engine bearings, shafting, rolling-mills, fans, and the wearing parts of many other kind of engines and machines.

Except when used as carriage-axle bearings it is difficult to obtain a reliable comparative test of the durability of bearing metal, owing to the impracticability of having the bearings in competition with each other, working simultaneously, and under precisely corresponding conditions; fortunately, however, the wear of a carriage axle bearing so accurately represents the varying speeds, pressure, &c., met with in one or other class of industrial machinery that an alloy which can successfully pass through the ordeal of continued use under a railway carriage is accepted with every confidence as applicable wherever bearings are employed. The manner in which Parsons' White Brass passed through this ordeal is most satisfactory. Two white brass bearings were put under one end of a Great Northern brake van, and at the same time two ordinary brass bearings were put under the other end, and the van was run 19,200 miles, or twenty-four trips to Edinburgh and back, and it was found that whilst the White Brass had diminished in weight but 2 ozs., the ordinary brass had lost no less than 2 lbs. 4 ozs. Under two third-class passenger carriages(same railway and conditions) the white brass lost 2½ ozs., against 1 lb. 6 ozs. and 1 lb 12 ozs. respectively of ordinary brass during 20,000 miles running; the locomotive engineer remarking that the bearings ran perfectly cool, and were lubricated with oil. The break-van bearing, after it had run the 19,200 miles and weighed, was replaced, and the following week the van was again put in a train, this time running 24,956 miles, or 31 trips to Edinburgh and back.

As the van then required varnishing it was in the shop at Doncaster for a month, when it was brought into use again, and up to the saturday preceding the date of the report it had done another 20,556 miles, making 64,712 miles in all, the locomotive engineer then writing—"These bearings are yet in very good order, and but little worn."

With such results as these it is not surprising that the manufacturers assert that the white Brass has been found, by carefully conducted experiments, to greatly surpass in durability all other kinds of anti-friction metal against which it has been tested, to reduce friction to a minimum, and effectually prevent heating of the journals. It is equally effective with quick as with slow speeds, and will work satisfactory under the heaviest weights. Some recent applications also show that it can be used with success to replace worn out bearings even when the journals have been greatly worn and scored from long continued use, without the necessity of returning them. The price of the white Brass being less than that of gun metal or ordinary brass, and its durability very considerably greater, a double saving is effected by its use—first, in prime cost, and secondly, in renewals and repairs, to which, in the case of railway carriages, heavy shafts, &c., which have to be lifted to replace the bearings, should be added the saving in the cost of labor, and the loss arising from stoppages.—*London Mining Journal.*

VAN NOSTRAND'S
ECLECTIC
ENGINEERING MAGAZINE.

NO. LXXXII.—OCTOBER, 1875.—VOL. XIII.

ELEMENTARY DISCUSSION OF STRENGTH OF BEAMS UNDER TRANSVERSE LOADS.

By Prof. W. ALLAN.

Written for Van Nostrand's Engineering Magazine.

III.

DOUBLE FLANGED BEAMS.

So far we have considered beams with rectangular cross sections, and beams of uniform strength deduced from these. We will now consider beams of ⌶ shape.

It is evident from the investigation already given of the condition of stress in transversely loaded beams, that those portions of the beam nearest the centre bear but a small proportion of the stress, while the contrary is the case with the outside fibres. Hence we would gain strength by moving a considerable portion of that about the neutral axis and placing it on the top and bottom.

The first form in which the idea was applied was in the T or ⊥ cast iron beam. The fact that rectangular cast-iron beam always broke by the tearing of the fibres on the side subjected to tension, suggested the idea of reinforcing that side of the beam with a flange. The result of this is, that the neutral axis still passing through the centre of gravity of the cross section, the extreme fibres subjected to compression are farther off than those subjected to tension, and consequently are strained more nearly to their full strength before fracture. This form of beam gives a large increase of strength for the same amount of iron.

It was still plain that the fibres in that part of the web about the neutral axis were but little strained as compared with the fibres on the outside, and it was proposed to leave as little material there as possible, and to place the mass of it in two flanges (⌶), one above and the other below, giving to these flanges sizes inversely proportional to the tensile and compressive strength of the material. The question then was, how much of the material should be left in the *web*, for plainly all could not be taken. The amount to be left is determined by experiment. If the web is left too thin, the beam will twist and break under the shearing force, and in some cases, from the want of stiffness in the compressed flange.

To simplify the calculations, the web is considered as bearing all the shearing stress, and no other, and the flanges as bearing all the extension and compression due to the bending moment; and these parts should be proportional accordingly with due reference to the practical difficulties that sometimes occur. The ordinary formulas for the strength of such beams are gotten by the following approximation: We first neglect the compressive and tensile forces of the

web, which are small compared with those of the flanges, and consider it as bearing only the shearing stress. Then as the depth of the flanges is generally small as compared with the depth of the beam, we consider all the fibres in each flange as strained alike, and as bearing the average stress that is brought on that flange. (Fig. 60.)

The resultant of the force on each flange, then, is equal to the stress on a unit of surface (S) multiplied by the flange area (A) : that is $= S\,A$.

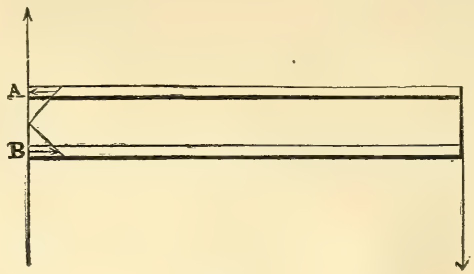


FIG. 60.

The point of application of the force will be at the middle of the depth of the flanges (at O and O′, Fig. 61). Fig. 61 shows the forces we have to deal with in the *Case* corresponding to *Case I.* under rectangular beams.

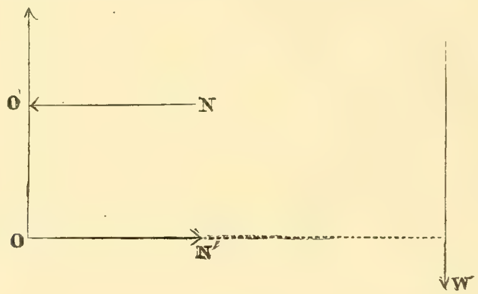


FIG. 61.

Let $O'\,O=d$.

S' = stress on upper flange per unit of surface.

S'' = stress on lower flange per unit of surface.

A'' = area of lower flange.

A' = area of upper flange.

Then if we take O (Fig. 61) as a centre of moments we have :

$$-N\,d-N'.0.+W\,x=0 \quad (\text{But } N=S'\,A')$$

$$\therefore S'\,A'\,d=W\,x \qquad (57)$$

If we take O′ as the centre of moments we will get

$$S''\,A''\,d=W\,x \qquad (58)$$

The formula for shearing force is identical with that under *Case I.* of rectangular beams ; that is :

$$T=W\,x \qquad (59)$$

If $A'=A''$, then plainly $S'=S''$ (from equations 57 and 58), or, the forces of tension and compression are equal (as in rectangular beams) ; but if A' and A'' are not equal, we have :

$$S' : S'' :: \frac{W\,x}{A'\,d} : \frac{W\,x}{A''\,d} :: A'' : A'$$

That is, the unit stresses in the flanges are inversely as the areas. Now, to have the material distributed between the flanges most efficiently for strength the unit stress should be in proportion to the ultimate strength of the material against tension and compression, and hence the areas of the cross sections of the flanges should be *inversely* as the ultimate strength.

Thus, if A D (Fig. 62) be of cast-iron, which is six times as strong against compression as against tension, the unit stress in the lower flange should be made

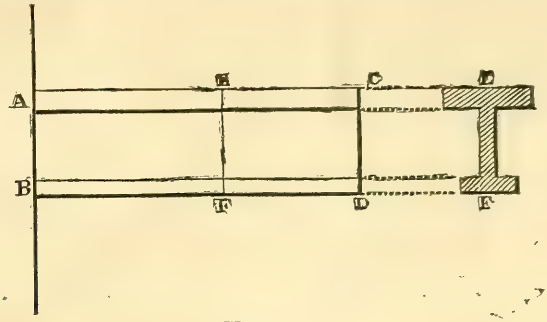


Fig. 62.

six times as great as in the upper, and to effect this the area of the lower flange should be one-sixth that of the upper.

The *Cases* under I beams are similar to those under rectangular beams.

Cass I.—Beams fixed at one end and loaded at the other.

$$S'A'd = Wx, \text{ and } S''A''d = Wx \quad (60)$$

Case II.—Beams fixed at one end and loaded uniformly.

$$S'A'd = \tfrac{1}{2}wx^2, \text{ and } S''A''d = \tfrac{1}{2}wx^2 \quad (61)$$

Case III.—Beams supported at both ends and loaded at some intermediate point.

$$W.\frac{n}{l}.x - W(x-m) = S'A'd, \text{ or}, = S''A''d \quad (62)$$

Case IV.—Beams supported at both ends and loaded uniformly.

$$S'A'd = \tfrac{1}{2}wx(l-x) = S''A''d \quad (63)$$

Case V.—A single moving load over a beam supported at both ends.

$$S'A'd = \frac{Wx}{l}(l-x) = S''A''d \quad (64)$$

Case VI.—A distributed moving load may be considered as included in *Case IV.*

The formulae for shearing stress are identical with those in rectangular beams.

The principles of the *uniform strength of beams* may be applied to flanged beams as they were to rectangular beams. The discussion is analogous to that already given.

MOMENT OF RESISTANCE OF BEAMS DETERMINED GEOMETRICALLY.

The following method of obtaining the moment of resistance of beams is of easy application, and in many cases of unsymmetrical cross section is the simplest that can be used :

I. For illustration, take a beam of rectangular cross section. Let G P (Fig. 63) be the cross section at some point of

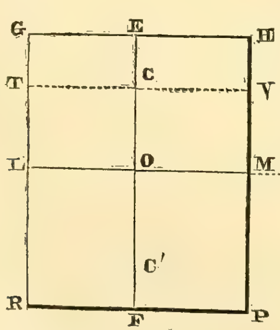


Fig. 63.

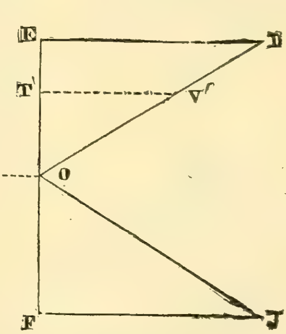


Fig. 64.

this beam. The stresses on the fibres, as we have already seen, increase just in proportion as we go from the neutral axis towards the upper or lower surface of the beam, and may for any vertical slice (as that at EF) be represented by the ordinates of two triangles, as shown in Fig. 64, where EI (=FJ) represents the stress on the outside fibre. For the cross section GP (Fig. 63) the stresses will be represented by two wedges, the bases of which are GM and MR, and the elevations of which are the triangles shown in Fig. 64. The volumes of these wedges give the amount of compressive and tensile force exerted at the cross section in question, and the points in GP under the centre of gravity of the wedges give the "centres of resistance," or the points of application of the resultants of these forces.

As a geometrical representation of the stresses on the fibres, these wedges are perfect, for the perpendicular ordinate of the wedge gives in every case the stress which exists in the fibre over which it stands. Thus the line T′V′ (Fig. 64) represents the stress on each fibre in the row TV (Fig. 63).

But it is often difficult to find the centre of gravity of these wedges in the case of curved and irregular cross sections, and yet this must be done before we can know the lever-arms of the stresses. To render this easier to do we may represent the stresses, not by wedges, but by *prisms*, the centres of gravity of which are over the centres of gravity of their bases.

Thus, if in (Fig. 65) we draw the two

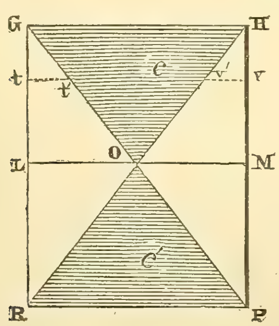


Fig. 65.

shaded triangles, and conceive prisms of a height = EI (the stress on the outside fibre, Fig. 64), to be constructed on them as bases, we shall have a geometrical representation of the stress on the section GP, less perfect in some respects than that given by the wedges but better suited to our purpose.

For, note that,

1. The volume of the prism GOH (Fig. 65) is equal to that of the wedge GM (Fig. 63), and the volume of any part of the prism cut off by a plane parallel to the neutral axis, as that whose base $t'Ov'$ is equal in volume to the corresponding part of the wedge TM, or since the height of the prism is constant, the stress on the surface GM as we go out from the neutral axis varies as the area of the triangle which forms the base of the prism.

2. The vertical slice of the prism standing on any line $t'v'$ represents in amount the stress on the line of fibres tv, for this stress is equal to the corresponding one in the wedge, the slice of the prism being as much higher than that of the wedge as tv exceeds $t'v'$. Of course (except in the case of the outside fibres in the row GH) each ordinate in the slice of the prism no longer represents the stress on the fibre over which it stands, as was the case in the wedge.

3. The moment of the tensile forces, for instance, will equal the area of the prism GOH multiplied by its height, (EI = stress on outside fibre = S). The centre of resistance of these forces, or the centre of gravity of the prism is at C (Fig. 65), the centre of gravity of the base GOH. The triangle GOH is sometimes called the "effective area" of

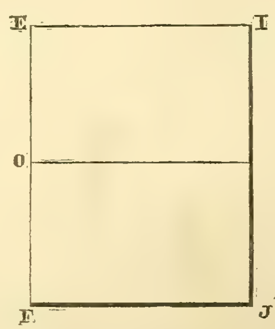


Fig. 66.

the surface GM, because a uniform stress on it of an intensity = the unit

stress at G H gives the same amount of resistance, as that on the whole area G M, acted on as the latter is by a varying stress.

Considering the stresses represented by the two prisms whose bases are G O H and R O P (Fig. 65), as concentrated at the centres of gravity C and C′ (Fig. 67) of these bases, and taking one of these points (as C′, Fig. 67) as the

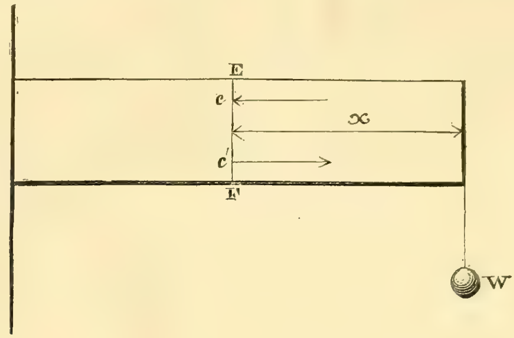


FIG. 67.

centre of moments, we have in the case represented in the figure :

$$(\text{Vol. of prism } G\,O\,H) \times C\,C' = W\,x$$

or if b = breadth and d = depth of beam

$$S\,(\tfrac{1}{4}\,bd).\ \tfrac{2}{3}\,d = \frac{1}{6}\,S\,b\,d^2 = M = W\,x \qquad (65)$$

as before.

Corollary. If the beam be square, $b=d$, and

$$M = \frac{1}{6}\,S\,b^3 \qquad (66)$$

II. As a second example, take a square beam so placed that its diagonal will be vertical. Fig. 68 is the cross section. Here we find the base of the prism of

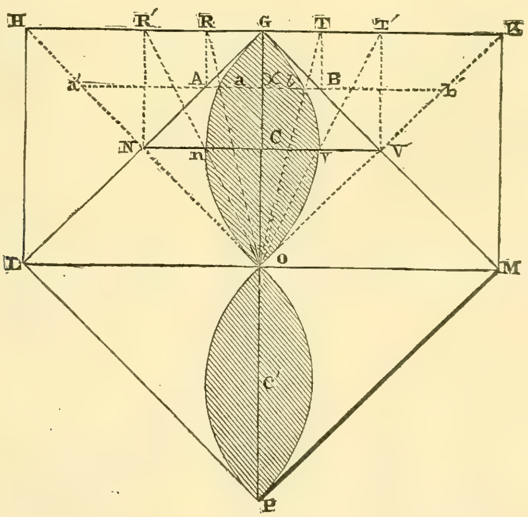


FIG. 68.

stress by points. To find the line in the base of the prism corresponding to the stress in any row of fibres, such as A B, whose distance from the neutral axis is O X, proceed as follows :

We see that if the cross section were the square of which H L M K is the half, then $a'\,b'$ would be the line required, since this is the breadth at that point of the triangle H O K, which would in that case represent the base of the prism of stress. Project the points A and B

upon H K. Then the actual row (A B) of fibres is as much shorter than the corresponding row in the supposed section H M, as R T is less than H.K, and consequently to obtain the proper line in the base of the true prism of stress, $a'b'$ must be shortened in this proportion. Draw lines from R and T to O. These lines intersect the row of fibres at a and b. Then

$$HK : RT\ (=AB) :: a'b' : ab \qquad (67)$$

Hence ab is the line required, and a and b are two points in the outline of the base of the prism of stress. Any number of lines as nv, &c., may be gotten similarly and the curve drawn through the points $a \cdot\cdot n \cdot\cdot b \cdot\cdot v$, &c., will give the form of the base of the prism of stress. This base is shaded in the diagram.

For any ordinate of the curve O n G, as aX, we have

$$OX : aX :: OG : RG = AX$$

But $AX = XG$ and making $GO = \frac{d'}{2}$ and putting $OX = x$ and $aX = y$, we have

$$x : y :: \frac{d'}{2} : \left(\frac{d'}{2} - x\right)$$
$$\therefore y = \frac{2}{d'}\left\{\left(\frac{d'}{2} - x\right)x\right\} \qquad (68)$$

This is the equation of a parabola with vertex at n, half way between H K and the neutral axis. Hence the base of each prism is composed of parts of two symmetrical parabolas.

Areas of the bases. Since the area of a parabola is *two-thirds* of the circumscribing rectangle, the area of each base

$$= \tfrac{2}{3}\,(GO \times nv)$$

But $nv = \frac{1}{2} R'T'$ and $R'T' = \frac{1}{2} HK$

$$\therefore\ nv = \tfrac{1}{4} HK = \tfrac{1}{4} d'$$

$$\therefore\ \text{Area} = \tfrac{2}{3} \cdot \frac{d'}{2} \cdot \frac{d'}{4} = \frac{1}{12} d'^2$$

The centres of gravity of these bases (and consequently of the prisms) are at C and C′, and the distance

$$CC' = \tfrac{1}{2} d'$$

Hence the moment of resistance of the fibres about C or C′ is

$$M = \frac{1}{24} S\, d'^3 \qquad (69)$$

(S=height of prism or stress on external fibres at G and P.)

Corollary. To compare the resistance of the beam in this position with its resistance when lying flat:

Let d=side of the square as L G.

Then $d' = d\sqrt{2}$ and eq. (69) becomes

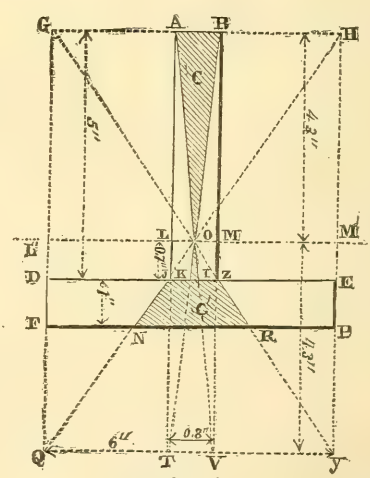
$$M = \frac{1}{12} S\, d^3 \sqrt{2} = \frac{1}{6\sqrt{2}} S\, d^3 \qquad (70)$$

Comparing this with eq. (66), we see that the beam offers greater resistance when flat in the proportion of

$$\frac{1}{6} : \frac{1}{6\sqrt{2}}$$

In solving these problems with diagonally placed beams, place the above value of M equal to the moment of the weight as before.

III. Let us apply this method to a **T** beam. Take for example the cast-iron **⊥** beam, calculated in part on p. 257 Rankine's Civil Engineering, in which the area of the flange = $\frac{6}{5}$ that of the web. Assume the flange to be 6 inches by 1 inch, and the web to be 5 inches by .8 of an inch, and draw a figure of the cross section to scale (Fig. 69).



Scale 1/4.

FIG. 69.

1. As the top and bottom of this section is not symmetrical, it is necessary to find the position of the neutral axis, which is no longer at the half-depth. This may be done by calculation, or by a simple mechanical process as follows:

The centre of gravity of the cross section, since this last is symmetrical with regard to the vertical line through the middle of the web, must lie on this line. Cut accurately the figure of the cross section out of card board, or tin, or good paper, and suspend it freely by one end of the flange, suspending also from the same point a plummet. Mark the line of the plummet on the card board, and the centre of gravity being on this line and also on the middle line of the web, will be at their intersection O. By measurement this point was found to be distant from A B four and three-tenths inches (4 . 3″), which is also the value by calculations. The line L M drawn through this point is the neutral axis.

2. To determine the bases of the prisms of stress. On the upper side the base is the triangle O A B, if the altitude be taken equal to the stress on the fibres along A B. For if L′ M′ H G were the upper half section, O G H would be the base of the prism and O A B is less than O G H, in the same proportion that L M A B, the real half section, is less than L′ M′ H G. Hence (if the upper be the compressed side) the total compressive force is equal to the prism erected on A O B, with the height equal to the unit stress at A B.

Below the axis L M.—For convenience we should have the height of the tension prism equal to that of the compression one, and the base must be determined under this condition. Complete the large rectangle G H Q Y, making the distance of Q Y below O=4 . 3 inches. Draw O Q and O Y and the shaded trapezoid J N R Z cut out on the flange by these lines, will evidently be the portion of the base due to the flange. Having prolonged the lines of the web to T and V, draw O T and O V, and then the shaded triangle O K I will be that part of the base due to the portion (L Z) of the web below the neutral axis.

The total tensile and compressive forces being always equal, and the height of the prisms having been assumed, each $=S'=$ stress on fibres at the distance of A B from O, the bases of these prisms must be equal also. This necessary equality between the area of O A B and that of O K I+J N R Z, affords a means of testing the accuracy of our work in finding the position of O.

3. Area of base O A B. This is,

$$=\tfrac{1}{2}\,(LA\times AB)=\tfrac{1}{2}\,(4.3\times.8)=1.72 \text{ sq. inches.}$$

4. To determine the distance C C′ (Fig. 69) between the centres of gravity of the prisms, which distance is the lever-arm to be used when one of these points is taken as the centre of moments. These centres of gravity (C and C′) can be readily determined by means similar to those employed in finding the centre of gravity of the cross-section itself. Thus, cut the shaded areas (Fig. 69) out of card board or paper, and suspending each of them from two points in succession, draw vertical lines through the points of suspension. The intersection of these two lines gives the centre of gravity. In the present case they may be so simply obtained by calculation, that we adopt that method. The centre of gravity of A O B is $=\frac{2}{3}$ the distance from O to A B or $OC=\frac{2}{3}(4.3)=2.87$ inches. As to the shaded part below O, by using the ordinary formula for the centre of gravity and taking moments around O, we find the distance

$$OC'=\left\{\frac{ONR\times\frac{2}{3}(1.7)-(OJK+OIZ)\frac{2}{3}(.7)}{ONR-2\,(OJK)}\right\}$$

$$=\frac{2.2764-.01388}{2.0145-.2975}=1.318 \text{ inch.}$$

Hence the distance

$$CC'=OC+OC'=2.87+1.318=4.18 \text{ ins.}$$

Hence, since S' is the height of the prisms, the moment of resistance of the fibres is

$$M=4.18\times1.72.\ S'=7.19\ S'$$

If it be desired to have M, not in terms of S', the stress along A B, but of S'' the stress on the lowermost fibres (at F P), we have since the stresses increase directly with the distance from O,

$$S':S''::L'G:L'F::4.3'':1.7''$$

$$\therefore\ S'=2.53.\ S'' \text{ and } M=18.19.\ S''$$

IV. As an illustration of the great saving of labor sometimes effected by this process, take the steel rail now widely used in England, the cross section of which is given to scale in

(Fig. 70). The determination of the moment here by calculation would be long and tedious. The dimensions of the cross section are given on the figure.

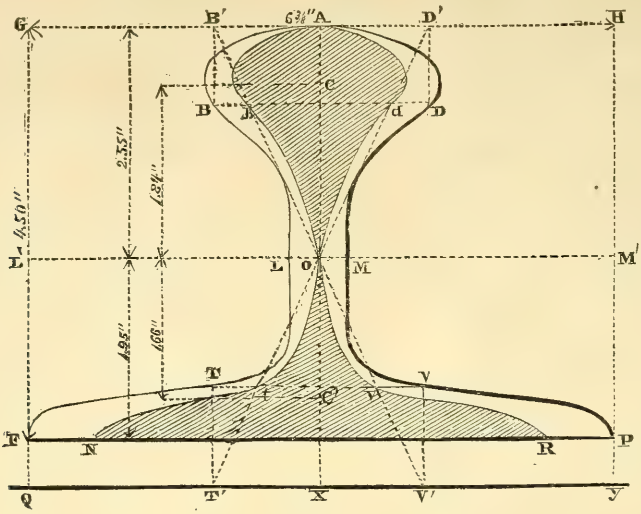


Fig. 70.

1. The centre of gravity O of the cross section is found by making a template as in the last case, and suspending it freely by a corner. The vertical through the point of suspension intersects A X at O, which is 2.55 inches below A. Through this point draw L M, the neutral axis.

2. The bases of the prisms of stress are determined by points as in example II.

Lay off O X=2.55 inches. Draw the rectangle G H Q Y. Assume the height of the prisms to be the stress in the fibre at A. Then proceeding as in example II., the line of the base corresponding to any row of fibres, as B D, is *b d*. Obtain any number of points in the same way as *b* and *d*, and through these points draw a curve bounding the shaded figure A *b* O *d*. Similarly below the neutral axis, *t v* is the line in the base of the stress prism corresponding to T V, and the shaded figure, O N R, is that base where the height is taken equal to the unit stress at A. The equality of the bases in area is the test of accuracy.

3. To determine these areas. The simplest plan in the present case is first to find the area of the cross section itself. This is done as follows: The rail in question weighed 84 lbs. per yard, and the steel, of which it was made weighed, .277 lb. per cubic inch. Hence if A=area of cross section in square inches

(36.A) .277=84 ∴ A=8.4 sq. inches.

Now cut out of the same card board, or paper, templates of the two shaded parts in the diagram, and also of the cross section itself, and weigh them. The ratio of the weights will equal that of the areas.

The comparison of weights may be readily made by means of a suspended wire, which may serve as a temporary balance, the templates to be compared being stuck on the opposite ends, and one or both moved until the wire is evenly balanced. The weights of the templates being inversely as their distances from the point of suspension of the wire, their areas will be in the same proportion. The areas of the prisms in the case before us were found to be equal each to 2.49 square inches.

4. The centres of gravity of these bases are found in the same way as those of the cross section itself. The point C was thus found to be 1.84 inches above O and C′ to be 1.66 inches below it. Hence the distance

$$C\,C'=3.5 \text{ inches.}$$

Therefore, finally, if S′=unit stress at A, the moment of resistance is,

$$M=2.49\times 3.5\times S'=8.715.\ S'$$

If we desire M in terms of S'' (stress at F P), we have

$$S' : S'' :: 1.84 : 1.66$$

$$\therefore\ S'=1.11\ S''\quad \therefore\ M=9.67\ S''$$

V. A circular cross section (Fig. 71). Here the neutral axis of course=L M, passing through the centre. Draw the circumscribing rectangle G Y and obtain the points $t, b, v, d,$ &c., in the curve bounding the base, as heretofore. Through the points so found draw the curves.

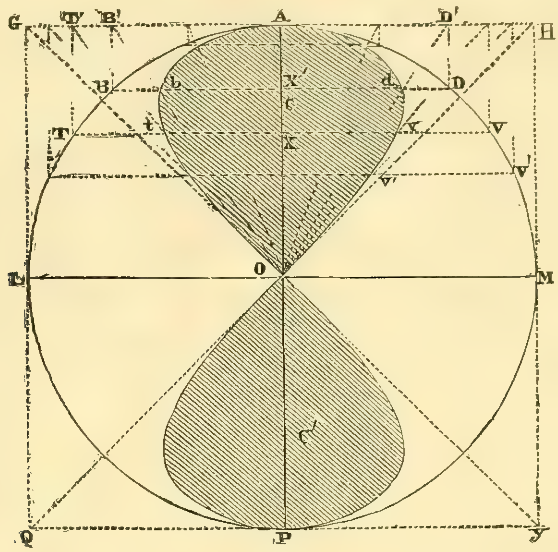


Fig. 71.

Determine the areas of the bases of the stress prisms by comparing them with the half-square G L M H. Thus, if a template is not to the surface of one of these beams it will just equal in weight the template cut to the surface A G L O $t\,b$ A, or, in other words, the shaded surface A b O d A is just one-third of the rectangle G M, or $\frac{1}{3}.\frac{d^2}{2}=\frac{1}{6}\ d^2$.

The centres of gravity C and C′ are found as before by means of templates. In this way it was found that

$$O\,C=O\,C'=.587\ (O\,A) = .\,587\,.\frac{d}{2}$$

$$\therefore\ C\,C'=.587\,d$$

The height of the prisms being S (= stress at A or F) the moment of resistance is,

$$M=S.\frac{d^2}{6}(.587\ d) = .0978\ d^3\,S$$

(The accurate value by calculation is $M=.0982\ d^3$ S.)

Note.—The curve of the base of the prisms is a *lemniscate.* To find its equation we have in the triangles O b X′ and O B′ A,

$$b\,X' : A\,B'\ (=B\,X') :: O\,X' : O\,A$$

And taking the vertical axis as that of X, and the horizontal one, as that of Y, the origin being at O, and calling the coordinates of the circle x' and y', and those of the *lemniscate* x and y we have:

$$y : y' :: x : R, \text{ or } y : \sqrt{R^2-x^2} :: x : R$$

$$\therefore\ R^2\,y^2=x^2\,(R^2-x^2).$$

Preservation of Metallic Sodium.—According to Bottger, if sodium be placed in alchohol until its surface becomes brilliant, and then in naphthalic ether chemically pure,. and finally in a concentrated solution of naphthaline in naphthalic ether, the metal may be preserved unalterable with its lustre unimpaired, for a long time.

THE CONVERTED RODMAN GUN.

From "Engineering."

We have recently referred to experiments soon to be made in the United States with some new forms of ordnance, among them being a cast-iron Rodman gun converted upon the Palliser system. Some interesting trials with this gun have been already carried out, and their results are so encouraging that the Ordnance Board have recommended that more of the cast-iron guns now forming the United States heavy armament should be converted in a similar manner.

The gun with which the experiments just referred to were carried out was originally a 10-in. smooth bore cast-iron piece. The bore was enlarged to a diameter of 13.5 in. and a wrought-iron tube 2.75 in. thick was introduced. The cast-iron shell had been made in 1866, the ultimate tensile strength of the metal was 32,369 lb. per inch, and the initial tension on the gun was 12,000 lb. The iron tube was manufactured by Sir William Armstrong & Co., and the clearance between the outside of the tube and the shell was about $\frac{1}{100}$th of an inch.

The gun had originally been made without preponderance, and by its conversion it became heavy at the muzzle. This would be the case with all the similar guns so converted, and it is proposed to overcome the difficulty by reducing the diameter of the trunnion from 10 in. to 8 in., removing the metal eccentrically, and then shrinking eccentric rings over the trunnions until their diameter is restored, and the centre of gravity is brought into the required position. A collar at the muzzle keeps the tube in the gun, and a screwed plug prevents it from turning. The rifling consists of fifteen grooves of equal width with the lands, the rate of twist being 1 in 40. The powder employed was that known as the double hexagonal grain, to which we referred on a recent occasion. The specific gravity is 1.7511, and the weight equals 80 grains to the pound. The dimensions of the grains are as follows: Width between faces of cones .7 in., width over all .75 in., width of faces at each side .32 in., thickness of parallel portion between bases of cones .15 in.

Two classes of projectiles were employed for the trial, known as the Butler and Arrick projectiles—to the former we shall refer again shortly with considerable detail—but only sixteen rounds were fired with the latter class.

The following are some of the leading particulars of the trial: Five rounds were fired with charges rising from 20 lbs. to 25 lbs., and weights of projectiles from 160 lbs. to 175 lbs. No change in the tube was detected after these firings.

Seven rounds were then fired with 35-lb. battering charges, and 173-lb. projectiles. After these rounds it was found that the tube had set at some points hard against the cast-iron shell, and that at the point of maximum pressure, the diameter had increased to 8.007 in.

With the same charge 38 further rounds were fired, of which 30 were with projectiles of 186 lb. weight; after these the greatest enlargement of the tube was .002 in. at the charge, and .003 at the projectile. Sixteen rounds were then fired with a different class of projectile, weighing 165 lb.; these gave very bad results, and were discontinued. They were succeeded by 50 rounds with 35-lb. powder charges, and 174-lb. projectiles, with a further enlargement of .001 at a position from 36 in. to 40 in. from the bottom of the bore, the tube at this point not having been previously extended. Sixty-three rounds were then fired, of which 50 were with projectiles weighing 187-lb. No further enlargement was detected, but beyond the trunnions the tube set out .002 in. One hundred additional rounds with 171-lb. projectiles resulted in a further enlargement of .002 in. at a point 24 in. from the bottom of the bore. These were succeeded by another 100 rounds, with similar charges and projectiles, and the increased enlargement was found to be .003 in. One hundred and forty-seven further rounds completed the total of 513, to which the gun has been already subjected, the final series causing an enlargement of .004 in., and the total increase in diameter being .018 in., counting from the twelfth round. Of the

above, however, sixteen rounds were fired with unsuitable projectiles, and the effect they produced may be fairly deducted, so that on 484 rounds fired with battering charges the enlargement was .011 in.

In conducting these experiments the velocities were measured with the Le Boulengé chronograph, and the Rodman pressure gauge was also employed. The maximum muzzle velocity was 1,459 ft., the mean maximum pressure with battering charges was 31,282 lb., and the maximum energy of projectile per inch of shot's circumference was 220,346 foot-pounds.

The results thus obtained are, it will be seen, highly satisfactory, and open up an effective mode for the improvement and strengthening of the United States ordnance, of which the cast-iron is the best in the world. The present armament of the United States for coast defence includes 1,294 ten-inch Rodman guns, and in their report the Ordnance Committee point out that these guns are at present useless for purposes of defence against armor-plated vessels, so that the casemates and batteries constructed at an enormous outlay, are comparatively useless, and must remain so, until the present armament shall have been replaced by new guns, or the present ones are converted into efficient rifles.

They consider that the trials already carried out with the 10-in. converted Rodman, are sufficiently encouraging to justify the expectation that by the same process the existing cast-iron guns can be converted into formidable weapons, but before recommending any extensive change, they propose to carry out further trials with another 10-in. and a 12-in. calibre Rodman, similarly converted.

THE FUSION OF STYLES.

From "The Architect."

From being the rallying points of two opposing camps in the architectural profession, the forms of architectural design long known as Classic and Gothic seem to be gradually entering into a strict bond of amity, and on the way to prove to the unprejudiced spectator that they are "not so very different after all." The time has at least gone by when the critic of decided leanings towards one or other school could arrange the sheep of Classicism on one hand, and the Gothic goats on the other. We are losing these sharp distinctions. Collections of architectural drawings, as in competitions, are no longer to be divided into designs with columns and pediments, and those with buttresses and pinnacles. If in such a gathering there is found a set of drawings of which the details are purely Roman, or one that can be safely referred to a particular quarter of the thirteenth and fourteenth century for all its precedents, it is commonly noted by the enlightened observer as "tame," and rewarded with faint praise accordingly; while his warmer commendations are reserved for designs which, spurning these trammels of a past day, present a union, or *réunion,* of features from both the main sources of the modern architect's inspiration; sometimes fortunately combined, sometimes reminding one of Portia's suitor from England, who she thought had bought "his doublet in Spain, his round hose in France, and his behavior everywhere." It would be natural that such a fusion of recognized styles should be practiced for some time by architects before its existence began to be observed outside the profession; but the fact is penetrating the non-professional stratum now; and as we read in a weekly literary contemporary the other day that the Queen Anne designs of the London Board Schools which are being erected are "in all their main qualities essentially Gothic," it is time to look about us.

And, on the whole, we think an impartial survey of the average buildings going on just now will show that Gothic and Classic have not met on quite equal terms, and that the latter is in fact having rather the worst of it, and is more or less succumbing to the Gothic. It is

true we have still a large proportion of buildings in which columns and architraves play an important part, and windows are adorned with little pediments and neat consoles; but the change is shown in these by the increased vivacity, variety, and relief of the carved decoration. No architect, with any concern for his artistic reputation, is content to adorn his building with the old stereotyped festoon and garland kind of thing, with no novelty of idea and no light and shade in execution. Gothic detail has overflowed into our Classic buildings, and carving is found on these which would be nearly as well in place on a building of manifestly Gothic type. But the converse is hardly the case. We do not often find details in any marked degree Classic in character introduced into Gothic buildings. The fluted column, and the facias of the architrave, do not find their way there, and would be pretty well killed if they did. The nearest approach to something of Classic feeling in our modern Gothic buildings is perhaps the use of the heavy square pillar, with carved capital, which may be regarded as a kind of modification of the pilaster; though, in fact, it is found in early Gothic building in the North of Europe especially; and perhaps Classic influence may be recognized also in the increased dimensions and more pronounced character of the horizontal cornice in modern Gothic buildings. It might not be very easy to say whether the leaning towards early and even Romanesque Gothic at present is a cause, or a consequence, of the feeling in favor of a kind of fusion of Classic and Gothic; but we are inclined to regard it as a consequence, and as arising almost unconsciously from a desire to secure the dignity of expression belonging to Classic architecture, and perhaps the fitness of its horizontal composition for practical purposes, without losing the variety and play of light and shadow so characteristic of Gothic work. Thus, in an indirect way, the Classic has influenced the main type of modern Gothic; but in regard to the direct visible effect of the one style on the other, there can be little doubt, as before observed, that Gothic is carrying the day, and is overrunning what would otherwise be Classic design with its own specialties of detail.

This fusion of Gothic and Classic is what has been preached some time back by certain critics, who may now see their ideas carried out to a greater extent perhaps than they ever expected. And perhaps any movement which gives us something in place of mere copyism deserves to be called a gain. But as we look at the buildings of this mixed type of architecture springing up around us we cannot say that it is clear gain. A much greater variety of manner, a (generally) much more ornate treatment we do see than under the old "pure style" method, and occasionally a really picturesque combination of detail resulting in a satisfactory and homogeneous effect. But in the main this homogeneous quality, this unity of treatment, is just what we miss in our new buildings; there seems a want of totality, of relation of parts, in them, accompanied too often also by a lamentable want of that refinement of detail which, after all, intelligent reproduction of a complete and uniform style at least secured to us. Our new buildings seem full of details that are quarreling with each other; full of contradictory emphasis. Carved ornament is crowded on more abundantly than thoughtfully; granite shafts with large spreading capitals are put wherever they can be got in; archivolts and window-heads are bemoulded and recessed so as to be quite over-heavy, and keystones are getting to such a size as to be sometimes double the length of the radius of the arch in which they are inserted. All this produces a certain novelty of effect, and the appearance of a great deal of elaboration of design; but it is, in one word, vulgar; and that is just the character of a great proportion of this nondescript architecture which is being produced at present. Details properly Classic would unquestionably look hard and thin if transferred to a Gothic building; but the converse is equally true, that details which would be very well in place in a design entirely and unaffectedly Gothic look large, coarse, and over-pronounced, when transferred to a design the main type of which is Classic. The two schools of detail will not really harmonize with one another, except to a very limited extent. But what is even more marked in the class of design of which we are speak-

ing is the loss of that unity and homogeneous structure which belongs to really good purely Classic or Gothic buildings. In these latter, at least, everything seems to be in its place, and to have a general coherence of treatment and style; a quality the value of which can scercely be overrated. And it is the evident loss of this in recent architecture which tempts one to doubt whether the escape from architectural reproduction, upon which we are sometimes felicitated, is by no means an unmixed gain. Such a building as Whitehall may be considered very artificial and cold in style; no doubt it is, but it has proportion and consistency of design, and is in perfect keeping with itself. And similar praise may be bestowed on a much greater building in every way, the Houses of Parliament. That the style selected for it is not in itself one of the best phases of Gothic is unquestionable; that it might have been treated with more power and effect one may be at liberty to think. But at all events there is a "oneness" about it; an entire keeping throughout, which we look for in vain among the buildings of the eclectic school. It is possible that by means of this experimental medley through which we are passing we may arrive at something both novel and coherent in the end; but it must be confessed there is not much indication of that at present. Novelty, no doubt, there is, plenty of it; but the old dignity of architecture seems to suffer sadly in the interim. And, with every wish that modern architecture should entirely emerge from mere copying, we may suggest that it is paying too dear for this to throw aside and ignore that coherency of style and design which has characterized all that we admire most in the architecture of the past; and that possibly a truer (though perhaps slower and more laborious) road to originality would be found in mastering the feeling and constructive principles of a complete style, and adapting that, freely and unreservedly, to the practical wants of the day, than in picking details out of different styles, in the vain hope of piecing them together into a new and "original" one; original only in the sense of having no origin.

One thing is unquestionable: that if this fusion of styles goes on at the rate which it seems to threaten, the business of architectural critics will become seriously and painfully complicated. It used to be sufficient to describe a building as Greek, Roman, or Gothic; everybody knew what was meant. But now the varieties of combination are so diverse and unexpected, that language fails in the effort to describe them in any concise form. The newspaper writers have been hopelessly bothered for some time back, and do not know what to call a new building now; and the professed architectural critic must succumb before long, and must either invent a new and very extensive vocabulary, or call upon the architect in each case to say what he wishes his design to be considered.

SPONGY IRON.

From "Iron."

At a recent meeting of the Newcastle-upon-Tyne Chemical Society, held in the theatre of the College of Physical Science, Mr. J. Pattinson, the President, in the chair, Mr. Gibb read a paper on "Spongy Iron."

Spongy iron, or iron sponge—the slightly cohering mass resulting when iron ores are reduced below the welding heat of iron, said the author—is produced in nearly all iron smelting processes, although it is a form of iron but little known in practice. Many proposals have been made to separate iron smelting into the two distinct operations of reduction to sponge, and the subsequent welding or melting of this product to produce malleable iron, steel, or cast iron. The earliest attempts on a large scale were those of Clay, under patents obtained in 1837 and 1840, and he has been followed by a series of inventors, of whom Chenot conducted the most elaborate recorded experiments. Efforts in this direction still continue; two processes, having for object respectively the manufacture of

puddle bar and steel, being now carried on on a somewhat large experimental scale ; and lately a series of extensive experiments were made by Siemens with specially planned furnaces that certainly reduced the ore to sponge, and melted the latter successfully so far as economy of working was concerned. But iron as sponge is in a most favorable condition for absorbing sulphur from the reducing agent and from furnace gases—a drawback that compelled Siemens to abandon this method of working.

Although the separate production of spongy iron, for the manufacture of iron does not give workable promise, the fine state of division of the metal in the iron sponge renders it very suitable for the precipitation of copper from solutions produced in the extraction of copper from its ores by the wet method.

For the use of spongy iron, in the reduction of sulphides, &c., in the dry way Bronæ and Deherrypon obtained a patent in 1859, and later in the same year Gossage patented the use of spongy iron, reduced from burnt pyrites in ovens or muffle furnaces, for the precipitation of copper from solution. In 1862 Bischof patented the manufacture and application of spongy iron for copper precipitation, his process and raw material being essentially the same as those described in Gossage's patent three years earlier. In 1863 Bischof patented an arrangement reverberatory furnace and accessory apparatus, for the production of spongy iron, for use in precipitation and other purposes. Henderson in 1863 and 1867, patented a variety of furnaces, and in 1869 Snelus patented a furnace similar to Gerstenhofer's pyrites kiln, for the production of spongy iron, but no one of their devices has been adopted. Proposals patented later than Bischof's have had, for main object, the production of sponge for the manufacture of iron and steel. Most of these have been some form of retort or muffle furnace in which the mixture is heated by transmission through brickwork, the retort being horizontal or vertical. This method is slow in action, and the wear and tear of the brickwork has proved too great in practice. Snelus' furnace, in which the finely-ground material falls from one series of bars to another in a reducing atmosphere, whilst maintained at a red heat, appears well adapted for the production of sponge, but its introduction being proposed for the manufacture of steel, the liability of iron in this state to absorb sulphur from furnace gases would probably prevent its adoption.

Siemen's cylindrical revolving furnace, although well adapted for quick and economical reduction, was abandoned for this reason. The vertical retort furnace has been again proposed by Blair, who states that he has overcome the former difficulties of working this class of furnace. In a vertical retort externally heated, unless the width be impracticably small, an excessive time is required for heating the mass through. Blair employs a shaft about 4 feet in diameter, and by the device of a cylinder, suspended in the throat and leaving an annular space only three or four inches wide, and heated internally by gas at the same time that the external shaft is kept heated, the ore enters the body of the furnace at a red heat, which is then readily maintainable in the mass. The reduced iron, passing down into a cooling shaft, is withdrawn from time to time whilst fresh ore and charcoal are charged into the annular mouth.

Only one form of furnace is now employed in making iron for precipitation. This is essentially a reverberatory furnace 30 feet long, with provision for conveying the flame under the hearth after it has passed over the charge. The hearth of the furnace is 23 feet long and 8 feet wide, and is divided into three working beds by bridges. Each bed has two working doors on one side. The doors slide in grooves and close air-tight. The fire is 4 feet by 3 feet, with bars 4 feet 8 inches below the bridge, thus allowing for a considerable depth of burning fuel. The fire door slides in grooves like the working doors. The hearth is formed of tiles sustained on brickwork partitions forming flues through which the flame returns after passing over the hearth. From these flues the flame drops, by a vertical flue alongside the fire-bridge, to an underground flue, communicating with a chimney. The entrance to the latter flue is provided with a fire-tile damper, which is closed whenever the working or fire doors of the furnace have to be opened. A cast-iron pan, 20 feet by 10 feet, is carried by short column

and girders over the furnace roof. In this pan the ore is dried and mixed with coal, and from it is charged into the hearth, through cast-iron pipes, built into the furnace arch. The furnace is elevated on brick pillars, to allow of iron cases running under it, to receive the reduced iron, and it is worked from a platform of cast-iron plates. A vertical pipe, 6 inches diameter passes through the hearth of the furnace inside of each working door, and through these pipes the reduced iron is discharged into iron cases placed beneath. These cases are horizontally rectangular and taper upwards on all sides. The cover is fixed and in its centre is a hole 6 inches diameter, with a flange upwards, which serves to connect the discharging pipe. The bottom of the case is closed by a folding door, hinged on one side, and secured by bolts and cutters on the other. The case is fitted with four wheels, clear of the door, and is covered with a cast-iron plate, fitting loosely into the opening on the upper side. It stands four feet eight inches high, and has a capacity of twelve cubic feet.

The furnace hearth being at a bright red heat, each of the three working beds is charged, with 20 cwt. dry purple ore and 6 cwt. ground coal, from the cast-iron pan over the roof. The fire and working doors are closed, and the only air entering is that through the fire, in working which care is taken to prevent the mass of burning fuel getting hollow. The charge in the first bed from the fire-bridge is reduced in from nine to twelve hours; in the second, in eighteen hours; and in the third, in about twenty-four hours. Each charge is stirred over two or three times during the period of reduction. Before opening any door the flue damper is closed, to prevent a current of air entering over the charge. On the complete reduction of the charge, on any working bed, two cases are run under the bottom pipe, to which their mouths are luted by clay, and the charge is quickly drawn into them, by rakes worked through the doors. The cases are then removed and closed with cast-iron plates. In about forty-eight hours the iron is cooled sufficiently to be discharged, and this is simply done by raising the case by a crane, and knocking out the cutters fastening the hinged door on the bottom, when from the tapering form of the case the mass of reduced iron falls out readily. The sponge is ground to powder under a pair of heavy edge stones, 6 feet in diameter, and is passed through a sieve of fifty holes per lineal inch.

For the manufacture of spongy iron for precipitation, two materials have been proposed, viz., burnt pyrites and "purple ore." The following are analyses of these materials:

	Burnt Ore.		Purple Ore.
Ferric Oxide	78.15	..	95.10
Iron	3.76	..	—
Copper	1.55	..	.18
Sulphur	3.62	..	.07
Cupric Oxide	2.70	..	—
Zinz Ozide	.47	..	—
Lead Oxide	.84	..	.96
Calcium Oxide	.28	..	.20
Sodium Oxide	—	..	.13
Sulphuric Acid	5.80	..	.78
Arsenic Acid	.25	.	—
Silicious residue	1.85	..	2.13
Total	99.27	..	99.55

Bischof and Gossage both proposed the use of burnt ore on the ground of the obvious economical advantage that the copper it contains is obtained, with the precipitated copper, without the expense of extraction. But burnt ore contains a notable portion of arsenic—.16 per cent. in above analysis—and this metal remaining in the sponge, is left mixed with the precipitated copper, and seriously deteriorates the quality of the refined copper ultimately made from it. Bischof states that, "should the ore have contained traces of metals, such as arsenic or lead they will be volatalized during the process of reduction." Whilst lead is reduced and in a great measure volatalized in the spongy iron furnace, the arsenic in such ores being present mainly as arseniates of copper and iron, which are likely to be reduced to fixed arsenes, is not volatilized, spongy iron made from burnt ores containing a proportion of arsenic closely agreeing with that in the ore. "Purple ore," which retains only the most minute trace of arsenic, is the only material now employed, and the following analysis gives the composition of spongy iron, made from purple ore by means of the furnace and method described above:—Ferric oxide, 8.15 per cent.; ferrous oxide, 2.40; metallic iron, 70.40; copper, .24; lead .27;

carbon, 7.60; sulphur, 1.07; alumina, .19; zinc, .30 ; silicious residue, 9.00 ; total, 99.62 per cent.

In using spongy iron in precipitating copper, the liquids are agitated by an air blast whilst the iron is gradually added. By this means a very perfect mixture is obtained, and a copper precipitate can be readily produced, containing not more than 1 per cent. of metallic iron. As compared with precipitation by scrap iron, the economy of space required and facility of manipulation are very great. On the side of spongy iron precipitation are cheapness of material and economy of application ; whilst against it is the presence with the precipitated copper of the unreduced iron oxides and excess of carbon from the reduction. In employing spongy iron, the copper extractor has the production of the precipitant in his own hands, and avoids the troublesome handling of a material so cumbrous as scrap iron.

As regards the chemistry of spongy iron precipitation, it is, of course, identical with that of scrap iron precipitation, and although it is stated by Bischof that, "some substances, such as arsenic especially, are only precipitated after the iron has been in contact with the solutions containing copper and these substances for several hours. The precipitation of the copper by my process being finished in a much shorter time, and the solutions then being separated from the iron powder, the above substances cannot be precipitated or mixed with the precipitated copper," the writer has been unable, with iron in any form or with copper solutions in any state, to completely precipitate copper and leave any, even the smallest, proportion of arsenic in solution.

The president says that a paper coming from such an authority as Mr. Gibb, was very valuable. From his experience of the temperature at which spongy iron was formed from oxide of iron, he wished to know whether it could be formed below a red heat, or was a continued red heat necessary for the formation of metallic iron ?

Mr. Gibb replied that he could hardly say. They took care to keep their furnace at least at a red heat, yet it was often worked at a very dull red heat at the flue end of the furnace, and the best iron was then made by a long way—the best iron for precipitation purposes; but it was simply a question of time; and it would be found that when the furnace went down to such a heat as that, instead of coming out in about twenty-four hours they were bringing it out in about sixty or sixty-two hours, which was a time quite inadmissible in pratice. But at a very dull red heat the iron was reduced, and reduced thoroughly, to a metallic state, but time must be given.

Mr. Scholefield wished to know whether it was stirred much during that period.

Mr. Gibb : Rarely ; now and again, but not very often. That was one of the things experience had shown should be done as little as possible, because with all the precaution of dampers and close fires and everything of that kind, it could not be stirred without air getting in, and they found the less it was stirred the better. It had to be stirred up or it would cake, particularly over the bed.

Mr. Lomas wished to know the thickness of the layers in those beds; if they perfected the process in each of these three divisions without removal from one end to the other; and if each was perfect by itself ?

Mr. Gibb, in reply, said that the thickness was six inches; that there was no removal, as there was a partition to prevent that; that each was perfect in itself, and that was why he said the bed next the bridge was completed in from nine to twelve hours. The flue bed took about twenty-four hours, and the others something between the two.

The President said, then the higher the heat the more rapid the formation of spongy iron.

Mr. Gibb replied, yes ; that was just the reason why, without having much experience in iron smelting, he doubted whether spongy iron would ever be made unless in such a great structure as a blast furnace, where no doubt spongy iron was made, and in fact no doubt all iron passed through that state, and where they had the quicker action of a reducing gaseous current. That was why he doubted altogether that spongy iron as a manufacture by itself would ever take its stand as a step towards another process, either smelting or puddling, in the manufacture of iron.

ON THE MEANS OF AVERTING BRIDGE ACCIDENTS.

Transactions of the American Society of Civil Engineers.

Report I.

To the American Society of Civil Engineers:

The Committee appointed, under the resolution of May 21st, 1873,* to inquire into the "most practicable means of averting bridge accidents, begs leave to report as follows :

After a careful examination into the causes of the most disastrous accidents which have occurred during the past few years, it finds that they can readily be divided into three different classes. First, where bridges are erected by incompetent or corrupt builders, and accepted by incompetent or corrupt railway or municipal officials. Second, where bridges of good design and sufficient material fail from absolute neglect on the part of their owners, or from injury to the material during transportion or erection. Third, where bridges, good or bad, are knocked down or destroyed by derailed trains moving at a high rate of speed, or where the growth of a neighborhood has brought a class of traffic on a bridge, which it was not originally designed to bear, either by the builders or the owners. How to treat each of these classes of causes will now be considered in the order above stated.

Accidents occurring from the first class would certainly not have taken place had the wrecked structures been correctly designed and had they possessed the proper sectional areas in their different parts —but failure from faulty design, is not nearly so frequent as failure from insufficient material. One great difficulty in the way of protecting the public from the results of imperfect design or scanty material lies in the absence of a fixed legal standard of loads and stresses for all classes of these structures, and another is the negligence of those controlling public works or those engaging in their construction, in securing skillful professional aid.

It would seem, therefore, to be our duty as a Society to establish in a few general terms—such as can be readily embodied in a law—a standard of maximum stresses and a table of least loads for which bridges should be designed, and to add thereto a practicable suggestion as to the necessary legislation required to give the public that protection which an adherence to this standard would afford. First, as to the standards for the least live loads to be used in proportioning bridges; a law which would provide that all railroad bridges should be built to carry not less than the following loads, would be well within the mark of safety.

For highway and street bridges the standard loads should not be less than as in first table on next page; for city and suburban bridges and those over large rivers where great concentration of weight is possible, as in column *A*; for highway bridges in manufacturing districts, or on level, well ballasted roads as in column *B*, and for country road bridges, where the roads are unballasted and the loads hauled are consequently light, as in column *C*.

Spans.	Pounds per square foot.		
	A.	B.	C.
60 feet and under...	100	100	70
60 to 100 feet.......	90	75	60
100 to 200 feet.......	75	60	50
200 to 400 feet.......	60	50	40

With the highway bridge the floor-beam strength is especially important, because of the great concentration of weight which may be carried on a single pair of wheels, therefore the floor

* At the Fifth Annual Convention, held at Louisville, Ky., May 21st and 22d, 1873, it was :—

"Resolved : in view of the late calamitous disaster of the falling of the bridge at Dixon, Ill., and other casualties of a similar character that have occurred and are constantly occurring, that a committee * * * be appointed to report at the next Annual Convention the most practicable means of averting such accidents."

The committee appointed consists of Messrs. James B. Eads and C. Shaler Smith of St. Louis. Mo., I.M. St. John of Quinnimont, Va., Thomas C. Clarke of Philadelphia, Pa., James Owen of Newark, N. J., Alfred P. Boller, Octave Chanute and Charles Macdonald of New York, Julius W. Adams of Brooklyn, N. Y., and Theodore G. Ellis of Hartford, Conn. Mr. Alfred L. Rives of Mobile, Ala., was appointed on the Committee but resigned.

system of each class of bridge should be —per floor-beam for each wagon-way—for city bridges, 6 tons; turnpike bridges 5 tons, and county bridges, 4 tons.

Span or Panel.	Pounds per Lineal Foot of Track.	Span or Panel.	Pounds per Lineal Foot of Track.
Under 12 feet.	6,000	Under 75 feet.	3,000
Under 15 feet.	5,500	Under 100 feet.	2,750
Under 20 feet.	5,000	Under 150 feet.	2,500
Under 25 feet.	4,500	150 to 175 feet.	2,500
Under 30 feet.	4,000	175 to 200 feet.	2,400
Under 50 feet.	3,250	200 to 300 feet.	2,250

The panel weights for railroad bridges are obtained by using the standard weight per foot for short spans. In computing all web members, one panel of panel weight is to be considered as preceding the standard span load. The proposed law should also provide that with the foregoing loads, the stresses or materials shall not exceed the following:

For wrought-iron in tension, long bars or rods................10,000 pounds per square inch.
For wrought-iron in tension, short links (for floor beams)...... 8,000 pounds per square inch.
For wrought-iron against shearing force......................... 7,500 pounds per square inch.

And for wrought-iron in compression, as in this table:

Diameters.	Pounds per Square Inch.		Diameters.	Pounds per Square Inch.	
	Square Ends.	Round Ends.		Square Ends.	Round Ends.
10	10,000	7,000	30 to 35	6,000	4,000
10 to 15	9,000	6,500	35 to 40	5,000	3,500
15 to 20	8,000	6,000	40 to 50	3,800	2,500
20 to 25	7,500	5,500	50 to 60	3,000	2,000
25 to 30	6,800	5,000	——	——	——

Where one end is square and the other end is rounded, a mean is to be taken between the two.

Cast-iron to be used in compression only, in lengths not exceeding 22 diameters, and at the same stresses as those prescribed for wrought iron.

The shapes under compression in the above are assumed to be hollow struts either square or cylindrical in section; other shapes than these to have the stresses varied as actual experiment may dictate.*

For wood the greatest allowable strains shall be as follows:

For oak in flexture...1 200 lbs. per square in.,
" pine " ".....1 000 " " " "

* Further experiments can alone determine the values to be used for other than square or cylindrical cross sections.—A. P. B.

and in compression as in this table:

Diameters.	Pounds per Square Inch.	
	Oak.	Pine.
10	1,000	900
10 to 20	800	700
20 to 30	600	500
30 to 40	400	300

The above standard should be changed or elaborated more fully, from time to time, as future experience and experiments on material suggest.

In order to secure to the public the full measure of benefit from the adoption of this standard, the law in question

should provide for the appointment by the governor of each state, of an expert whose duties would consist in having cognizance of the construction and maintenance of every bridge intended for public travel in the state or states for which he was appointed. The law should also make it imperative that the expert so appointed shall pass an examination as to his mathematical and mechanical competency, which it is suggested, should be by a standing committee of this Society, regularly constituted for the purpose, and that the appointment of any such expert who fails to receive the endorsement of this committee shall be null and void. Under the proposed law it should be the duty of all railroad, city, county or state officials having charge of the letting or construction of bridges to call upon this expert—first, to examine the strain-sheet of the proposed structure before work has been commenced, to certify to its correctness if correct, or to make such alterations as may be necessary if it is faulty in design or scant in material according to the legal standard ; next, to be present on the completion of the bridge, and then and there to make a critical examination of the work in all its details, comparing and verifying the sections on the strain sheet with those of the actual structure, and if these last are insufficient, to forbid the use of the work until the law is fully complied with ; and lastly, if the bridge is up to the standard in all its parts, to obtain from him a certificate to that effect, copies of which certificate shall always be given to the builder, and filed on record in the proper department of the state government. This officer shall also see that a tablet or plate is placed on a conspicuous part of the bridge, bearing the names of the builders, his own name, and that of the officer of the railway or corporation who accepts the work, together with the strength of the bridge as designed, and the year of its erection.

Accidents arising from the first class of causes would be nearly, if not quite prevented by the general enforcement of the foregoing provisions. Against accidents occurring from causes of the second class, the law should further provide that all railway or other corporate bodies, when having a bridge built, to be used for public travel, shall be compelled during the erection of the work, to keep on the spot a competent inspector, who shall have the power to reject any piece of material which may have been injured in transportation or while being placed in position. Also that all railroad and city bridges shall be inspected once every month by a competent person in the employ of the corporation owning the bridge, for the purpose of seeing that all iron parts are in order, all nuts screwed home, that there are no loose rivets, that the iron rails are in line and without wide joints, and that all wooden parts of the structure are sound and in proper condition.

It should also be the duty of the state officer before mentioned, upon any bridge being reported as in a neglected condition—whether the report be an official one or made by one not connected with the corporation—to proceed to the spot and examine for himself, and if he finds the bridge in a neglected or dangerous condition, he should cause the owners to put it in safe order without delay.

In relation to the third class of causes —destruction by derailed trains, high winds, or by concentration of living weight owing to the growth of cities or neighborhoods—prevention is less easy, but much can be done by carefully designing the structure. In most of our railroad bridges the floor system is the weak point. The cross-ties are short, the stringers are proportioned for a train *on*, not *off* the rails; and the guard-timbers are too low, and are insufficiently bolted. A derailed engine on such a floor as this, plunges off the end of the cross-ties into the open space between the stringers and the chords, and generally wrecks the bridge. To obviate this, the law should provide that, first,—all cross-ties shall extend from truss to truss, they shall be placed so close to each other that if supported at the proper intervals it will be impossible for a derailed engine to cut through them, and the stringers shall be so spaced as to give them this support. Next, the guard-timbers shall be scantlins not less than 9 × 10 inches, and they shall be strongly bolted or spiked to at least each alternate cross-tie. And lastly, the clear width between the trusses on through bridges shall be so great that the wheels

of a derailed train will be arrested by the guard-rail before the side of the widest car can strike the truss. Where switches are placed at the end of a bridge, the Wharton or some other form of safety switch should be used.

Against the majority of accidents from high winds, a provision in the law requiring that all lateral bracing shall be sufficient to resist a pressure of 30 pounds per square foot of truss and train, will be sufficient. Lateral bracing can be proportioned at 15,000 pounds per sqnare inch against this particular strain, as it is of very rare occurrence.

The last case in the third class of causes of accidents is where a bridge built originally for a neighborhood or country road becomes too weak for the requirements of a growing community or possiby of a newly established manufactory; also where a railroad bridge, intended only for that class of traffic, has a highway floor subsequently added to it. Against the first contingency, the vigilance of the state official and a chance that some of the users of the bridge may occasionally notice the tablet setting forth its strength, would seem to be about the only safeguard; but in the second case the law should provide that—except by permission of the state officer in charge of bridges—no corporation or other bridge owner shall add to the dead weight on a bridge without at the same time making the proper addition to its strength.

The foregoing provisions, if embodied in a law, will afford the public about all the protection which is readily obtainable in the case.

No mention is here made of the quality of the material, as the proposed officials engaged in carrying out the law will be men who have been passed on by the Society, and the very fact of their surveillance will be apt to produce care in this regard. In addition to this, the standard stresses have been placed so low that the use, whether accidental or fraudulent, of low grades of iron will hardly endanger the work. A provision in the law that all bridge details shall possess the proper proportional strength to that of the main members of the bridge, and a series of instructions from the examining committee of the Society to those who pass their examinations for appointments under this law in reference to these proper proportions, will protect the purchasers of bridges from insecure details of construction.

In addition to his duties, as above defined, the state officer in charge of bridges should also visit the scene of any accident in his district as soon as possible after the occurrence, and remain during the removal of the wreck, or until he is able to ascertain the true cause of the failure. The facts in the case should then be reported by him to the examining committee of the Society.

In conclusion, it is here advised that a committee be appointed to draft such a law as is outlined in this report; that a resolution be passed by the Society recommending the adoption of this law by the different state legislatures, and that printed copies of this report, the proposed laws and the accompanying resolutions, be sent to the members of the Society with a request that they move actively, each in his own state, towards procuring the passage of the specified law by the various state legislatures during the coming winter.

Jas. B. Eads, Chairman.

Oct. 30th, 1874. C. Shaler Smith. *

* In advocating the views presented in the foregoing report, the undersigned is actuated by the following reasons.

First—the resolution under which the Committee is acting requires from it "the most practicable means of averting—*i. e.*, preventing bridge accidents," rather than the mode of sitting in judgment on them after they occur.

Second—as the national legislature has for some time been passing laws for the protection of life on navigable waters of the United States, prescribing qualifications and standards for engineers and pilots, the proportions of safety valves, &c., for boilers, and appointing examiners and inspectors under these laws, so, sooner or later will the question of the proper construction of railways be taken up and legislated upon.

Third—many mistakes have been made in these laws, owing to ignorance on the part of those passing them, and the undue influence of interested inventors and manufacturers, and each succeeding Congress has had amendments to make in order to repair some injustice or supply some omission.

Lastly—as laws regulating the construction of railroads and bridges will certainly be enacted, and official positions will assuredly be created by them, it is far better that this Society should take time by the forelock, dictate a law which will be just and equitable, and hold control of the appointment under it, than that it should stand in the background, until an aroused public opinion compels legislation which may be injurious to the profession, especially if enforced by political appointees who may be utterly unfit to fill such positions. All laws are written by some one, and the greater the knowledge of the subject matter on the part of that person is, the more probable the production of a good and wise statute.

Hence the undersigned believes that the fixing of the standards as proposed, the preparation of such a law as suggested, and the professional surveillance of the appointees under it, are eminently the province of this association, and that all legislation on the subject should be both inspired and dictated by the most prominent authority in the premises--the American Society of Civil Engineers.

April 18, 1875. C. Shaler Smith.

REPORT II.

The undersigned differ from the views expressed in the foregoing report, and present the following as an expression of their own :

1.—They agree with the report, that it is desirable the American Society of Civil Engineers should publicly declare what it considers to be a standard bridge, anything below which is not to be deemed as a safe and durable construction. But they do not think it is desirable to go much into detail, as they believe it to be impossible to construct a specification that will meet all cases. Incompetent engineers cannot be prevented from building bad bridges by any specification however elaborate; they therefore are content with laying down general principles, leaving the application to others, and offer the following standard specification for bridges of iron and wood:

Spans—Feet.	Pounds.	Spans—Feet	Pounds.
100 and under.	100	300 to 400	60
100 to 200	80	Over 400	50
200 to 300	70	——	—

1. Every highway bridge shall be capable of carrying, in addition to its weight, a moving load per square foot of roadway and sidewalks as follows :

2. Every railroad bridge shall be capable of carrying on each track in addition to its own weight, 2 locomotives coupled, weighing 30 tons on drivers in space of 12 feet, and whose total weight, including loaded tenders, is 65 tons each; said locomotives to be followed by so many loaded coal cars weighing one ton per lineal foot, as will cover the remainder of the span.

3. Bridges shall be so proportioned that the above loads shall not strain any part of the material over one-fifth of its ultimate strength.

II.—The signers of the foregoing report, propose to cause future bridges to come up to the standard by a system of inspection, the inspectors to be passed by the Society before being appointed. The undersigned believe that in the present state of public opinion this is impracticable. If any inspectors are appointed, it will be by political influence, and the results will be worse than at present, as the inspection will be insufficient, and yet, to a great extent, relieve the owners of bad bridges from legal responsibility.

The undersigned consider that the most the Society can hope to do, is to provide means in case of the fall of a bridge, by which the responsibility of imperfect construction (if this was the cause of the accident) may be fixed on designers and builders, and iron manufacturers.

It is therefore recommended that the Society prepare and present to the state legislatures, a petition embodying the following data:

1. That the standard of the American Society of Civil Engineers shall be the legal standard, and in case it should be found that any bridge is of less strength than this, it shall be taken as *prima facie* evidence of neglect on the part of its owners.

2. That no bridge shall be opened for public traffic until a plan, giving the maximum loads it was designed to carry, the resulting strains, and the dimensions of all the parts, sworn to by the designers and makers, and attested by the signature of the proper officer representing the municipality or corporation by whom it is owned, be deposited in the archives of the Society, and that the principal pieces of iron in the bridge be stamped with name of maker, place of manufacture and date.

The result of this will be, that in case of the fall of a bridge, the responsibility can be directly and easily traced to the right party, which at present cannot be done, and the Society should willingly aid to such a purpose. This, it is recommended, should thus be done: the Society to appoint a committee—with compensation to be fixed by law—which, upon the call of the executive of any state, should visit and report upon any fallen bridge, care being taken that no parties interested in the construction of the bridge be upon the committee.

It is believed by the undersigned, that the knowledge all bridge builders would have that their misdeeds, if any, could, by this process, be traced home to themselves, would make them very careful in the future, and eliminate all failures of imperfect design or material.

As to the inspection of existing structures; if the society assumed the first duty, this would soon fall under its jurisdiction, and if it would volunteer the duty—in case any plan was deposited obviously unsafe—to protest against it, that also would be well; such would have prevented the fall of the Dixon bridge, and the lamentable loss of life and limbs there occurring.

THOS. C. CLARKE.
Feb. 1st, 1875. JULIUS W. ADAMS.

REPORT III.

The undersigned differ from the views expressed in the foregoing reports, and respectfully present the following :

1. The members of the committee agree that it is meet and proper the American Society of Civil Engineers should determine the standard strength for all bridges to be built in this country, and they further agree in the main, what this standard should be. The differences in opinions grow out of the methods for incorporating this standard in the every-day practice of the country. Two general modes present themselves for so doing; the one legislative and compulsory, and the other looking forward to directing public sentiment to right conclusions by a thorough dissemination of the adopted standard.

2. The undersigned advocate the latter method as the true policy of the Society, believing that any attempt to influence the enactment of laws that would be so far-reaching as the ones proposed, is impracticable, if not contrary to the genius of the Society itself. They further believe that when once public sentiment is aroused by the publicity which should be given to the adopted standard, it will compel the passage of laws covering the question.

3. The undersigned therefore suggest that the report to be accepted be simply one covering a standard strength for all bridges, in as general terms as possible, with a recommendation that such standard be widely disseminated by circular and the public prints, and that copies be distributed among the legislative bodies of the several states.

The following standard, culled from the foregoing reports, is proposed for adoption :

4. For highway bridges, as submitted in Report I.

5. For railroad bridges:*—the structure shall be at least capable of carrying on each track, in addition to its own weight, 2 locomotives coupled, weighing 30 tons on drivers in space of 12 feet, and whose total load, including tender, is 65 tons each. Said locomotives to be followed by as many loaded coal cars, weighing one ton per lineal foot, as will cover the remainder of the span.

Bridges to be so proportioned that the above described loads shall not strain the several parts in excess of one-fifth or one-sixth of the ultimate strength. In determining the strains produced by the above standard, it is to be understood that the chord system is to be computed for a uniform loading, while the web strains must be based upon the irregularly distributed or concentrated loads produced by the above described train, in its passage from one end to the other.

The following table represents the uniform distributed moving load for different spans :

* Being the same as submitted in Report II, page 129.

Span or Panel.	Pounds per Lineal Foot of Track.	Span or Panel.	Pounds per Lineal Foot of Track.
12 feet.	5,250	75 feet.	3,000
15 feet.	5,250	100 feet.	2,750
20 feet.	5,000	150 feet.	2,500
25 feet.	4,500	175 feet.	2,400
30 feet.	4,200	200 feet.	2,300
50 feet.	3,250	200 to 300 feet.	2,250

The extreme panel weight for all spans is obtained by using the standard weight per foot for short spans.

6. Under the standard loading, as expressed in above table, materials should not be strained in excess of what is submitted in Report I.

All of which is respectfully submitted.

ALFRED P. BOLLER.
March 1st, 1875. CHAS. MACDONALD.

REPORT IV.

While agreeing in many important particulars with the report of the Chairman of this Committee, the undersigned holds the views expressed by some of the other members regarding the expediency of compulsory legislation on the subject. It is believed that the opinions of the Society as a body, advanced for its interest and benefit and that of those who should choose to be governed by them, would have more weight and influence than though the Society should assert itself as a competent authority upon bridge construction. If this Society adopts a well defined standard of strength for bridges, it is believed that the public generally will wish to conform to it, and engineers even who are not members will be glad to avail themselves of the united opinion of so many of the profession.

There seems to be a unanimity of opinion among the members of the Committee as to what constitutes the ordinary load upon a railway bridge, and but a slight difference of opinion as to its amount.

From an examination of the weights carried upon many of the principal railways in the United States, it is found that the heaviest engines weigh about 2,830 pounds per foot; and that three, and sometimes four, are coupled. The heaviest weight on one pair of drivers is from 21,000 to 24,000 pounds, and the weight on all the drivers, generally not exceeding 12 feet wheel-base, is from 72,000 to 84,000 pounds. The heaviest trains may be assumed to weigh 2,250 pounds to the running foot, exclusive of the engines. As the coupling of more than two engines is mainly upon snow roads, it is not believed they should be included in a general rule for proportioning bridges, but should be classed among those exceptional cases for which a general provision cannot be made.

In view of the above, it is believed that all railway bridges should be proportioned for a rolling load of 3,000 pounds to the foot for the total engine length, and for 2,250 pounds to the foot for the remainder of the bridge; that bracing on each system should be proportioned to sustain 84,000 pounds on any 12 feet of track, and that any point on the track should sustain 24,000 pounds.

It is not believed that the system of expressing the loads that a bridge should carry, by so much per foot with a varying amount for each length of span, is the best; but if such a standard is to be adopted, the table in the report of the Chairman is believed to be the best of those given, although it is somewhat below the loads actually carried by many roads in this country.

The floor-beams of railway bridges should be proportioned for not less than the following loads:

Spaces.	Pounds.	Spaces.	Pounds.
4 feet apart, or less.	28,000	12 feet apart, or less.	42,000
6 feet apart, or less.	31,500	15 feet apart, or less.	45,000
8 feet apart, or less.	35,000	More than 15 feet apart	3,000 to the foot.
10 feet apart, or less.	38,500		

The following table is offered as embracing the foregoing loads when reduced to so much per lineal foot:

For intermediate lengths of span the proportional number of pounds per foot should be taken.

These loads do not include the extraordinary weights that are sometimes drawn over railways in this country; such as heavy pieces of machinery, blocks of stone, or a locomotive of different gauge on a truck car, nor more than

Span or Panel.	Pounds per Lineal Foot of Track.	Span or Panel.	Pounds per Lineal Foot of Track.
12 feet and under.	7,000	50 feet.	3,000
15 feet.	6,000	100 feet.	2,800
20 feet.	4,800	200 feet.	2,600
25 feet.	4,000	300 feet.	2,500
30 feet.	3,600	400 feet.	2,450
40 feet.	3,200	500 or over.	2,400

two engines coupled. These are exceptional cases which can be provided for when they may be expected to occur, and the weight can ordinarily be distributed so to cover a sufficient length of track as not to exceed the loads above given.

For the effect of wind, the maximum strain is believed to be about 40 pounds per square foot horizontal, and about 20 pounds per square foot vertical.

For highway bridges, the following table is offered as a substitute for that given in the report of the Chairman for the three classes of bridges named :

Spans. (Intermediate lengths in proportion.)	Pounds per Square Foot.		
	A.	B.	C.
100 feet and under.	100	75	60
200 feet.	80	60	50
300 feet.	70	50	50
400 feet.	60	50	50
500 feet and over.	50	50	50

The floor-beams and flooring should be of sufficient strength to sustain the following loads on four wheels :—Class A, 24—B, 16—and C, 8 tons respectively. These do not include the extraordinary loads sometimes taken over highways. They are exceptional cases and the weight can generally be divided.

With regard to the factors of safety to be used, it is believed that a less factor is required for the permanent and unchanging dead load, than for the vibrating and uncertain live load, which may, by accident, be increased beyond the limit for which it was computed. This, together with the fact that a larger factor for the dead load gives no additional strength to the bracing near the middle of the span, but only at the ends, leads to the following substitution for the factor offered in the report of the Chairman.

For wrought-iron and steel in both compression and extension—for the dead load including snow, $\frac{1}{3}$—for the live load including wind, $\frac{1}{6}$ the ultimate strength.

For cast-iron in compression only, and for lengths of not more than 20 diameters—for the dead load $\frac{1}{6}$, and for the live load, $\frac{1}{10}$ the ultimate strength. For large masses, as in arches, a factor of $\frac{1}{4}$ the ultimate strength may be adopted.

Bridges should be tested with the maximum loads which they are intended to sustain A less load would seem to be of but little use, and a much greater one might unnecessarily strain the structure. The load should be applied gradually, and the moment any undue deflection or crippling is observed, or the slightest diminution in the transverse section of any bar is occasioned, the load should be immediately removed and never repeated. If no actual rupture occurs, the bridge will probably be safe with 0.4 of the test applied. The acceptance of all bridges, after being constructed with proper proportions for the material used, should be subject to such a practical test.

THEODORE G. ELLIS.

April 20th, 1875.

AN EGYPTIAN RAILWAY. — A great railway in Egypt, from Cairo to Khartoum, is progressing rapidly ; it is proposed to extend it westward to Darfur. Plans have been prepared for a line from Khartoum to the frontier of Abyssinia, the acquisition of that country by the Egyptian Government being regarded as only a question of time.

—*Engineering.*

THE "DIRECT PROCESS" IN IRON MANUFACTURE.

By THOMAS S. BLAIR, Pittsburgh, Pa.

Transactions of American Institute of Mining Engineers.

I feel a certain sense of responsibility in bringing before you the subject of the direct process in iron manufacture. I am aware that, in such a body as I have the honor of addressing, there are few who are not already so well informed upon its past history that it would be a weariness to them to listen to anything else than an account of practical success. Yet, to claim that success involves so much that, if I do not make good my claim, I deservedly expose myself to severe criticism.

The whole literature of the art, so far as it relates to the direct process, is, up to this time, but a history of failure. It is safe to say that more money, time, and talent have been fruitlessly spent in the pursuit of this object than in all the other unsuccessful efforts in the whole line of iron metallurgy. A distinguished authority in patent law has remarked that "the invention records of the United States and of foreign countries are filled with the waifs and abandoned relics of these abortive struggles."

Dr. Percy, whose great work may be taken as an epitome of all that was worth mention, whether useful or curious in pig-iron metallurgy, up to the date of its publication (1864), after giving elaborate accounts of various attempts at the direct process, condenses his own opinion of all that had been then effected, into a brief but summary comment upon a pamphlet of one of the sanguine inventors who had said: "It is evident that the present mode of working iron ores, whether rich or poor, is not the most rational or economic one, although almost the only one in general use. They convert iron already malleable into cast iron, to be reconverted at much labor and cost, into malleable iron again."

To this Dr. Percy rejoins: "These questions are extremely obvious. They have been repeatedly proposed before, but never yet satisfactorily answered." Elsewhere he speaks of Chenot (who came so near success that the jury of the French Exposition of 1855 thought he had attained it, awarding to him one of the great gold medals; and Le Play pronounced his invention "The greatest metallurgical discovery of the age") as "poor Chenot," and ridicules the claims set up for him.

Gruner in his "Steel and its manufacture," 1867, translated by Lenox Smith, 1872, says: "Several metallurgists have thought that instead of smelting ores in a blast-furnace, it would be better to simply reduce them to the condition of soft or carburized sponge. They hoped to obtain purer products and consume less fuel by operating at a lower temperature. They were completely deceived. When the sponges are made, instead of cast-iron we have blooms of less purity, since they contain, besides the usual cinder, the earthy substances in the ore. And if the sponges are melted in crucibles instead of forging them directly in the form of blooms, we shall have a homogeneous product, but it will be iron or crude steel of inferior quality, unless the iron sponge undergoes fining like pig-metal. In the direct methods whose object is the abolition of blast-furnaces, the addition of carbon mixed with the ore cannot be avoided; and it is this which destroys all profit in the processes invented by Chenot in France, Renton in America, Gurlt in Germany," etc.

Bauerman who comes later than Percy (1868), gives but slight attention to the direct process. Speaking of the various processes for the direct production of wrought iron from the ore, he says: "As these methods are only applicable to the treatment of easily reducible ores and are essentially slow in work, giving only a small production from a plant of considerable extent, as compared with the open fire (Catalan forge), they have not as yet been found to possess sufficient advantages to be generally adopted on a large scale.

Crooks and Rohrig's work (1869), adapted from Professor Kerl's Metallurgy gives small encouragement. In the volume on iron they say, in their difinition of wrought iron: "It is usually

produced by the conversion of pig-iron, and, in rare cases is obtained direct from the ore." And again, under the caption, "Methods for Making Wrought Iron Direct from the Ore:" "At present this process is seldom used on account of its numerous disadvantages. It requires pure, rich, and easily fusible ores, and is performed in interrupted operations; much iron is scorified, the consumption of fuel is very large; and lastly the product is seldom uniform, and is mixed with slag, which can only be removed by repeated welding." After describing the Catalan forge, etc., they proceed as follows: "Gersdorff roasts sparry iron ore in reverberatory furnaces, and heats the roasted ore, together with coal, in crucibles. Clay heats ore and coal in a retort, and treats the reduced iron in a puddling furnace. Renton reduces the iron ores in vertical, slightly heated tubes, by means of carbonic oxyde gas, and forms the reduced iron into balls in a puddling furnace. Chenot submits the ores to a reducing roasting, to transform them into magnetic oxyde, which he finally crushes, and by means of an electro-magnetic apparatus, extracts the magnetic components; he then reduces the ore with carbonic oxyde gas, grinds the resulting spongy iron, mixes it with soda, presses into cylindrical shape, and at a suitable temperature draws it out into bars. Roger heats the iron, together with coal, in a rotating cylinder, and forms the balls in a puddling furnace. None of these methods seem to have met with any practical success."

In their volume on steel they say, under the heading, "Steel Direct from the Ore:" "Gurlt proposes to treat rich, pure iron ore in cupola furnaces by means of carbonizing and reducing gases, and to melt the resulting product in a gas reverberatory furnace, but this method has not proved successful when carried out on a large scale. By Chenot's method, rich, pure, ores are reduced in cupola furnaces by interstratified layers of charcoal; the resulting spongy products containing various amounts of carbon, are sorted and ground in mills, and the mass is pressed into cylinders and melted in crucibles, sometimes together with coal and a purifying and scorifying flux of manganese. This method has been tried in Belgium without economical success, and it does not permit the production of cast steel containing a fixed proportion of carbon.

The newest and most promising way of producing steel direct from the ore is Mr. Siemens' method with the regenerative gas furnace. This is the method described by Mr. Siemens before the Chemical Society of Great Britain, May 7th, 1868. The main feature is the vertical hoppers in which the ore was to be reduced, and the product dropped thence into the bath of an open-hearth furnace. (Further on we shall see that Mr. Siemens states that it has been abandoned.) Neither Kohn nor Fairbairn appear to have thought the subject worthy of serious notice.

Under the date of February 27th, 1869, we have the record of the opinion of a metallurgical chemist, known to you all as an eminent authority. I allude to Mr. Geo. J. Snelus. I quote from an English patent granted to him, of the date just mentioned: "In the ordinary process of making iron, the ore is reduced under such conditions that it immediately takes up carbon and is converted into cast iron. Several attempts have been made to produce wrought iron direct from the ore, but either owing to the process not being continuous, or its requiring too much time and fuel, or its inapplicability to the treatment of fine ore, and *the incomplete reduction* of the ore, none of these attempts have yet been successful in such a degree as to afford the means of making iron or steel so economically as can be done by first forming pig-iron in the blast-furnace."

On this side of the Atlantic, with one notable exception, the direct process received little attention in the literature of iron metallurgy. The exception I refer to is the report of Dr. T. Sterry Hunt, addressed to Sir W. Logan, Director of the Geological Survey of Canada, 1869. In this report the author says: "In accordance with the well-known fact that the reduction of oxyde of iron takes place at a temperature very much below that required for subsequent carburization and fusion, it has been shown that the charge of ore in the blast-furnace is converted to the metallic state some time before it descends to the zone in which melting takes place. It forms, when reduced, a spongy mass,

readily oxydized, which, by proper management, can be compressed and made to yield malleable iron, or by appropriate modes of treatment, may be converted into steel. This fact has been the starting-point of a great number of plans designed to obtain malleable iron and steel without the production of cast iron and the employment of the processes of puddling and cementation. This, it is true, is attained in the Catalan and blooming forges, *but the attention of many inventors has been, and still is, directed to the discovery* of simpler, or at least more economical, methods of obtaining similar results."

Dr. Hunt then proceeds to sketch all the direct process, in this country and abroad, worthy of mention, up to the date at which he wrote, pointing out in each case the difficulty or drawback developed in practical working. It is a brief but comprehensive history of the subject, and tells the same story in every case,—failure to reach any large results.

The British Iron and Steel Institute may certainly be taken as embodyidg the latest and most advanced ideas in everything that relates to iron metallurgy. At its meeting in London, March 19th, 1872, the discussion which arose respecting the Danks puddling furnace, brought out incidentally an expression of opinion on the direct process from some of its most eminent members. Mr. Edward Riley said: "As regarded making wrought iron direct from the ore, he believed there was certainly very little hope of that being carried out practically or profitably. He thought no one could conceive any method more simple than the present process of throwing materials into the blast-furnace for the purpose of reducing them, and he was sure that all improvements in iron should commence with the pig-iron. They could make it in any quantity, and they ough to start there. He could not conceive of any other process of making iron cheaper."

Mr. Isaac Lowthian Bell "thought that a certain amount of disrespect had been shown," in a previous part of the discussion, "with regard to the blast-furnace, in speaking of it as a roundabout way of doing the work which was performed by it. There was no doubt that they combined the iron with the carbon or silicon in the smelting process, which had subsequently to be dispersed; but they must remember that the blast-furnace, at the same time, got rid of earthy impurities generally found associated with iron ores. He therefore quite agreed with Mr. Riley that, although it might be a roundabout way in the first instance, they could not conceive any means so simple for getting rid of a large amount of extraneous matter as blast-furnaces."

These views appear to have been acquiesced in by the members generally. At their meeting in April, 1873, Dr. C. W. Siemens read a paper which, from the distinguished position of its author, and the character of its reception by his associates, may reasonably be supposed to represent the condition at that date of the art of iron making in Great Britain, so far as relates to the direct process. After describing the various attempts made by him to bring the direct process into practice, and explaining the reasons which induced him to abandon them, one after the other, he uses these words: "These experiments convinced me that the successful application of reduced ores could not be accomplished through their conversion into spongy metal, and fully explained to me the want of success which has attended the previous efforts of Clay, Chenot, Yates, and others, to produce iron direct from the ore." He then describes a new method and apparatus wherein he begins by abandoning one of the cardinal features of a truly direct process, a feature pointed out by Dr. Hunt in the extract I have already quoted, viz., that the reduction of the oxyde of iron can be obtained at a heat much below that required for its consequent combustion and fusion. Dr. Siemens, despairing of realizing this feature, begins, in his new process, by fusing the oxyde.

Such, I think, may be called a fair statement of the literature of the subject up to the present time. Furthermore, its uniform and consistent record of failure is borne out by the facts. It would have been, for example, impossible for a metallurgist so intelligent and deservedly esteemed as Gruner is, to commit himself to the statements I have quoted, if, at the time he made them,

there had been in existence, as an article of manufacture on a large scale, a *true* iron sponge. He speaks of the "earthy substances" as causing "impurity," and says that the sponge when melted will, it is true, give a homogenous product, but of inferior quality, "unless the iron sponge undergoes fining like pig-metal." Had he been acquainted with iron sponge whose only "impurities" (in quantities sufficient to be objectionable) were silica and alumina, could he have fallen into the error of stating that the impurities could not be removed by the state of fusion, but only "when the iron sponge undergoes fining like pig-metal?"

So with his statement that the necessity of adding carbon in the direct process "destroys all profit" in it. Had he been acquainted, I say, with true iron sponge, and familiar with its manufacture into iron and steel, he would have recognized the fact that in iron sponge we have the least possible affinity between the earthy substances and the metal. And he undoubtedly would have been thus informed had such practice been known in the art.

But setting aside all these, I come down to the present hour and present place, and our own country, and I ask you here present, who are familiar with all the industries of the nation, whether you have knowledge of any direct process for the production alike of iron and steel, now carried on upon a working scale, as a successful rival of the ordinary indirect methods?"

When one considers that the immense results which must flow from the successful achievement of the direct process are understood by all scientific men, and have been by them so understood for years past, it seems like presumption to attempt to carry off a prize which all have hitherto either despaired of, or, seeking, have failed to win. It seems so plain, so easy, yet has still remained, as it were, just out of reach. There must be, one would say, some hidden but insuperable difficulty, else the problem had long since been solved. Consider for a moment how inviting a field it is. Nature provides us with the metal we want, chemically combined with oxygen, and mechanically mingled with other substances. Let us withdraw this oxygen from the iron only, leaving the rest as compounds, it alone being elementary. Now let us melt the product, so that the iron shall, simply by difference of gravity, be separated from the dross, and then poured into proper moulds. Here we have but two steps, each of great apparent simplicity—first, reduction; second, fusion. Such is the ideal, which by contrast makes the old system appear so crude, unscientific, and roundabout, that the term "direct" applied to the new method sounds like the promise of a great and beneficent revolution.

We know that carbon at a certain heat will dissociate the iron and the oxygen, yet leave the other mineral matter of the ore unreduced, giving metallic iron—wrought iron—as the result. We know further, that we have at command furnaces in which the product can be melted down in a bath of cast iron, and so treated that it shall result in ingots of any desired degree of carburation. We know that if the reduction of the ore can be effected the elements of cost in fuel, labor, etc., will make the product cheaper than pig-iron, and also that the melting process is less costly than puddling, whereas its product is of far greater value. Why is it, then, that while the whole iron industry of the world is struggling by small economies to realize a return upon its capital, this most plain, most prominent of all economies remains unpractised?

There has been a link missing—without it, all is naught. There has been no thorough, uniform, economical process of reduction. The missing link is true iron sponge. It is that which I come here to exhibit to-day; to tell you how it is obtained, and to show you that, by the means I shall describe, it is within the reach of all. Let me be your guide while we travel together, in thought, from the point at which I started to the final point of success. It shall not be the path I traveled. This time we will take the smoothest and shortest way.

We are in a chemical laboratory. We take a small porcelain tube and fill it with a mixture of pulverized peroxyde of iron and charcoal; next we seal the ends of the tube hermetically, then expose it to heat, by immersing it in a bath of brightly red-hot sand for a certain time (varying with the character

of the ore), then take it out, cool it, and, after cooling, break it open, and pour out the contents. Carefully separating and testing them, we find that we have obtained particles of metallic iron. Now what condition did we observe to get this result?

First. There was contact of the iron oxyde with carbon.

Second. There was isolation from the free oxygen of the atmosphere.

Third. There was the heat of bright redness.

Fourth. There was a certain duration of time.

Fifth. There was continued isolation from the air until cold.

Hence, we have established the fact that if a peroxyde of iron be brought into contact with a sufficient quantity of carbon, with perfect isolation from the atmosphere while exposed for a sufficient length of time to a sufficient heat, and then cooled down to a sufficient degree while still isolated from the air, the oxygen and the iron will be dissociated, the oxygen passing off in a gaseous form, leaving the iron behind. Now, chemistry supplies all the data for filling up with absolute figures the blanks in this statement, and we have in consequence a formula by which, if strictly carried out, we can achieve the first of our two great steps in the direct process—we can gain the metallic iron directly from the ore. Hence the chemistry of the operation is clear, and it becomes simply an engineering question how to meet all the necessary conditions, so as to conduct it on the large scale.

First, we investigate previous attempts, striving to detect what is defective, recognizing what is correct, and supplying what yet is wanting. Proceeding in our course of elimination we first reject all those methods in which it is sought to yoke the production of the iron sponge directly with a method of treating it; those, for example, which are meant to reduce the ore in one chamber and pass it as fast as reduced (or supposed to be reduced) into another chamber for after-treatment—welding, melting, etc. The operations cannot be made synchronous. One or the other must be disarranged in order to accommodate its fellow.

Confining ourselves, therefore, to the simple question of reduction, we finally give the preference, among the multitude of contrivances and appliances, to the vertical chamber, to be filled at top, and drawn at bottom, and working continuously. But in all these we discover one fatal defect; there is no adequate provision for the isolation of the material, either while under treatment, or cooling, or both.

We experiment ourselves, and despair of obtaining the desired result by any arrangement of valves, or slides, or the like contrivances. The dilemma is this: we want an apparatus that, as I have said, shall work continuously, and on a scale of considerable magnitude, taking in and discharging material at short intervals, yet always closed to the entrance of free oxygen. Or, otherwise stated, we must have a chamber so open at top and bottom that we can dump in a cartload of crude material above and draw out a cartload of finished product below, yet be all the time hermetically sealed against admission of air. Now this chamber—assuming that we have settled upon the plan of filling it with ore and solid carbonaceous matter, and heating them through its walls—must be surrounded by heat for a certain distance down and by a cooling medium below that, because we intend to reduce and then cool down. Well, we find that our difficulty as regards the keeping out of air at top, takes care of itself. The solid oxygen and solid carbon, down in the zone of reduction, are combining as carbonic oxyde, and, by virtue of their great expansion, forcing their way upward and out so that they arrest every particle of free oxygen before it can penetrate downward. As to the bottom, however, we have not this resource, and must find another. We get it by giving to our chamber such proportions that there shall always be above the place of egress a column of material, so cool itself as to be proof against the influence of oxygen, and of such a height as to form a packing, which shall seal up all that material above it which has not yet reached the safe degree of cooling.

By this device, which, surely, is as simple as anything in metallurgical engineering, our dilemma is answered. We are now operating, in regular practice, at Glenwood, cylinders of three feet

internal diameter, and forty feet in height, whch are open tubes, so far as relates to the taking in and discharging of their contents, but as relates to access of air in their working zones, are sealed retorts; the seal above being the ingoing material itself and the gases percolating upward through it; and the seal below, the material which, by cooling, has become indifferent to exposure. For the first time, then, in the history of attempts at the direct process we have at our command complete isolation, yet continuous working.

Let us next take up the question of imparting and maintaining the necessary heat. Here at once another difficulty confronts us. We must work upon a scale of considerable magnitude, and our reducing chambers must, therefore, be of considerable area. But their contents are very poor conductors of heat, and a little experience will convince us of the impracticability of getting an evenly-distributed temperature by conduction from the outside through a mass of, say, three feet diameter. Now, we must have uniformity of temperature to get uniformity of result, and the system we have adopted obliges us to impart the heat by conduction. We could conduct it, we will say, through three inches of the materials, in time enough to answer all practical purposes, but not through three feet.

Let us see, therefore, if we cannot bring every particle of the material within three inches of a sufficiently heated surface. Thus stated, you will probably guess at the solution of the problem. It is this: When charging your material into your cylinder, cause it to pass between heated surfaces in streams whose greatest distance, in any part, from a sufficiently heated surface, shall not exceed your limit of three inches.

This, you will readily perceive, may be done in many ways. Let me describe to you one of the arrangements which I employ. It accomplishes very economically the purpose just explained, and performs another function which I will refer to directly.

In the top or mouth of the reducing cylinder, I suspend an inner cylinder or thimble of cast iron, with walls, say one inch thick, and having an outside diameter of twenty-eight inches.

Now, the reducing cylinder has an inside diameter of thirty-six inches; hence there is left an open space or annulus between the two of four inches across.

I charge my materials into this annulus only, so that all have to pass downward through it, and none can be more distant than two inches from the heated surface, either of the cylinder or of the thimble. I make the thimble long enough—say six feet—to insure that all the materials shall have acquired the temperature desired before they descend below the annulus.

This "initial heating," as I call it, establishes one of the primary conditions with which we started out—the imparting of the necessary degree of heat—the only duty required of that portion of the heating chamber which surrounds the cylinders below the level of the bottom of the thimble being to prevent the escape of the heat thus imparted. You will observe that this device completely meets the whole difficulty as to the conduction of the heat, so that—whatever the diameter of the reducing cylinder—it is only a question of what diameter and length you will give the thimble, in order to impart your materials the temperature you wish.

We have now got thus far. Our reducing furnace shall consist of one or more cylinders (adopting the cylinder as the preferable form of chamber), which shall be heated externally for a certain distance from the top down, then cooled the rest of the distance downward to the base, excepting the room required at bottom for raising the telescopic sleeve for the discharge of material.

At its top is the thimble for initial heating.

Let us now revert to our original statement of the conditions to be met, and see if we have fulfilled them.

First. We provide the contact of iron ore and carbonaceous matter by mingling them before discharging into our cylinder.

Second. We isolate these materials from free oxygen while in the zone of reduction.

Third. We conduct the required degree of heat through the mass.

Fourth. Our apparatus enables us to hold it under treatment for any length of time desired.

Fifth. We have continued the isolation until the product was too cool to be oxydized on exposure to the air.

Thus we have realized, upon a working scale commensurate with the requirements of the art, the laboratory experiment of the sealed tube, and the manufacture of iron sponge becomes as simple as any of the ordinary operations in the art of iron making.

From the general principles above laid down, it will be easy to plan a good working reducing furnace; but there are a number of details, both of construction and management, which I think may interest you.

I have already alluded to the thimble arrangement for the "initial heating," as having another recommendation beyond its convenient form. What I referred to is this: When the carbon dissociates the oxygen from the iron, carbonic oxyde is formed, and this, rising as I have said, passes outward by way of the interior of the thimble, as furnishing a line of less resistance than the annulus, packed as the latter is with the ingoing materials. As it ascends through the thimble it is met by the air, which, in virtue of its greater weight (being colder), and from the tendency to transfusion in gaseous bodies, descends into the thimble, and a perfect combustion of the carbonic oxyde is kept up.

Thus the carbon, which had served as a chemical agent in the reduction of the ore, is made to do duty once more, as a fuel.

Speaking of fuel, I would say that my method of heating the cylinders is to place the portion of them to be heated in a chamber of brick, which is supported on iron pillars; thus leaving the cooling zone accessible below. This chamber is heated by letting into it streams of gas at different levels, with an air inlet adjacent to each inlet of gas. All, of course, are arranged so as to have the gas supply under convenient control. Aside from the economy of gaseous, as compared with solid fuel, it is incomparably easier to keep a chamber such as this at a uniform temperature with gas than to heat it by burning coal or wood on grates.

While on this subject of fuel, I may say that I am tired of the ordinary form of gas-producer. It is certainly a clumsy affair.

I hope to have something interesting to say, upon a future occasion, as to a better form throughout. Meantime I would suggest to others who find the clinkering to be as much of an annoyance as I do, to try—as I shall soon—in the present form of producer, a water-tox all round, as high up as clinkers borm, and water-bars like those somemes used under boilers.

I not only introduce the gas into the heating chamber, but also carry a pipe into and project it downward nearly to the bottom of the thimble. By this means, whenever the gases developed in the cylinders, as before explained, do not suffice to keep the heat of the interior of the thimble up to the point desired, I turn on other gas enough to make up the deficiency.

Thus I secure perfect control of the heat of the thimble, and make sure that the material in the annulus will always be hot enough to be ready for dropping when a charge is drawn from below. In this way the output of the furnace is limited to but one consideration, to wit: what duration of exposure to a red heat is necessary to perfect the conversion. The amount of fuel required for heating is about one-third of a ton of iron in the sponge turned out. Any description of fuel commonly used in gas producers will answer. As to the cooling, the reducing cylinders underneath the heating chamber are prolonged simply in wrought iron of one-fourth inch thickness, and each is surrounded by a jacket, which is kept full of water continually changed. The wrought iron cylinder ends about eighteen inches above the floor, and a sleeve, working telescope fashion, closes the remainder of the connection when let fully down. By raising the sleeve more or less, as required, the material gushes out underneath, and as it does so the whole column of material in the cylinder descends, leaving a space at the top of the annulus, which is immediately filled up with fresh material.

I do not find that the size of the ore makes any practical difference, whether it is, say, two inches through, or any smaller. This fact has been observed in experimental work heretofore, but I have never seen, nor been able to frame for myself, any explanation that is quite satisfactory. I suggest it as an interest-

ing subject for our fellow-members of the chemical profession.

It has been stated in the books that the sesquioxyde of iron in the process of reduction first becomes magnetic oxyde, then protoxyde, then metallic. This appears to be demonstrated by the fact which may often (if not always) be observed in pieces too large to be "done through" (as the workmen phrase it), in the time during which they were under treatment.

If the size of the piece is large, say four inches, and the core is still quite raw, but the outside completely reduced, the concentric layer next to the core will be protoxyde, the next magnetic oxyde, and the next the iron sponge. Not that these layers are distinctly defined, but merge into each other at the points of contact. But if the size is kept within the limit named, there is usually no distinction to be observed, and the pieces, if anything near raw at the core, will usually show signs of protoxyde on the surface.

I must, however, qualify my remark as to the comparative time required for the reduction of pieces of different sizes. I did not mean to include ore in fine particles. This does appear to be more rapidly reduced than that which is coarser, but as it is cheaper to break the ore only to a moderately small size, and the fine powder is hence an insignificant fraction, I have not observed it closely in this particular.

With respect to the time required for treatment, it varies according to two sets of conditions.

The first is that of chemical composition. The sesquioxydes are more easily reduced than the magnetic, and the latter than the protoxydes. Hence, hasty reasoners, who might argue that because the sesquioxyde had to pass through the stages of magnetic and protoxyde before becoming metallic, it must, therefore, be the hardest to reduce, would find themselves in direct opposition to the fact. The explanation, I suppose, is this: Where the oxygen most abounds, reduction is easiest to commence, and once on the move, the operation proceeds rapidly.

The second set of conditions are those of mechanical structure. The massive materials are, as one would naturally suppose, harder to operate upon than those which are loose and open. The brown hematites are capital subjects for the reducing furnace. As soon as they reach a red heat, the water of combination is driven off, leaving an open, sponge like structure, and being also sesquioxydes, we have both the chemical and mechanical conditions for speedy reduction. The compact hematites, such as the Iron Mountain ore of Missouri, and the red specular of Lake Superior, though sesquioxydes, have no combined water, and are of a dense structure. In consequence they require a much longer treatment. The magnetic oxydes, such as those of Lake Champlain and the iron sands of the St. Lawrence, being both very compact, and leaner in oxygen, require a longer time still than the compact hematites; while the protoxydes, when in such a shape as, for example, the dense tap cinder from the puddling furnace, are extremely obstinate under treatment.

Among the curiosities of the reduction of iron oxydes, is the fact that the intensity of action bears but slight relation, within certain limitations, to the degree of heat employed. This is a fact noted by Mr. I. Lowthian Bell, in his experiments with the blast furnace. It suffices for our present purposes to state, as relates to it, that there would be no particular acceleration of the process gained by pushing the heat to a degree that involves danger of welding the material together while under treatment.

But I am able to announce to you another very important fact, and one not to be found in the books, namely, that at the temperature of reduction—say a fairly bright red heat, and with carbon alone as the reducing agent—no carbon whatever is taken up by the iron. I think it sufficiently indicates the state of the art of iron-sponge making as it has been hitherto, when I tell you that I asked this question direct of one of the most distinguished and most practical of the foreign authors I have already quoted, and the answer was that, to the best of his knowledge, the point had never been settled. Now, if you will consider for a moment the immense importance of this question—the question whether your product is to be wrought iron alone—a product which you can employ as iron or carburize with precision to the

temper desired, or whether it is to become an unsettled and uncertain carbide of iron, to be sampled and analyzed, every lot, before using, and from which carbon must be removed if wrought iron is to be made from it; when I say, you consider the magnitude of this question and the fact that neither the man of science nor the practical manufacturer had any answer for it, you will agree with me that the art had not yet made much progress.

But at all events, the question is now set at rest. I have had frequent analyses made of iron sponge, produced from various descriptions of ore, and in no case has combined carbon been found. The iron sponge, sensitive as it is to many chemical reactions, only takes up carbon (when presented unaccompanied by an accelerating agent) as other wrought iron does, to wit: at the recognized heat of comentation, a heat far higher than we need to (or ought to) employ in the reducing furnace.

With respect to the carbonaceous matter used as the reducing agent, I would state that, in regular practice, we have, up to the present time, made use of charcoal. We have tried both coke and anthracite, but merely in an experimental way. We have not been prepared to remove the sulphur from either, and—having so many other things to get into working order—have preferred to run no risks in this particular. Our experiments have been conclusive, however, as to the reducing power of these substances, and we shall, early in the spring, take measures to use coke from washed coal. We have experimented with a Bradford separator, and find that the fine "slack" of the Pittsburgh coal can be so freed from sulphur that even, if none were driven off in coking, and the whole of it absorbed by the iron in the reducing cylinder, there would not be over 0.08 per cent. in the iron. For the country east of the Alleghenies, the anthracite culm should furnish an exceedingly cheap reducing agent. I am informed that there is no difficulty in removing the sulphur by treatment with steam charged with alkaline vapors, and at moderate cost. I have not yet had any practical experience, however, in this matter.

The estimate of quantity required per ton of iron produced is very easily made. For brevity's sake we will consider only the sesquioxydes, as they require the largest ratio of carbon. They carry 70 per cent. of iron to 30 per cent. of oxygen. Now, every 30 parts, by weight, of oxygen take up 22½ parts of carbon, so that we employ 22½ parts of carbon for every 70 parts of iron, or 32.14 parts of carbon to the 100 of iron; in round numbers, one-third ton of carbon to the ton of iron in the sponge. It may occur to you that this is the theoretical quantity, and that in practice it must require more. But such is not the case—at least to any appreciable extent. No carbon is used in the reducing cylinder except what is taken up by the chemical operation referred to above. None of the other oxydes of which the ore is composed are reduced, and there is no free oxygen present to consume any carbon. Whatever excess, beyond the amount absolutely required, we may mix in with the ore, to secure a sufficiency throughout the mass, is regained at the bottom of the cylinder.

I would now ask your attention to the fact that, in my statements respecting reduction, I have hitherto confined myself to the case of reduction by carbon only. You are aware, however, that there are certain substances, such as cyanogen, hydrogen, etc., which, when present with carbon, exert a singular power in accelerating its combination with iron. Some of these substances, as, for example, hydrogen, are also in themselves powerful reducing agents. You will see at once how the employment of these may vary the results. The hydrocarbons, for example, will produce reduction at a lower temperature or with great saving of time, but will yield an irregularly carburized sponge. The field is too large to enter upon here, and must be passed over with this brief notice, to be reverted to, however, for a moment when I come to speak of the second branch of the direct process, viz., fusion.

There is another feature of the reducing operation which has been remarked, upon by some accurate observers, such as Mr. I. Lowthian Bell, but which appears to have been unsuspected by the generality of those who have attempted to make iron-sponge. It is this, that the

resistance of the oxygen against its dissociation from the iron increases in inverse ratio to the quantity remaining. Thus, to get out fifty per cent. of it, for instance, is a very easy and a very short operation ; to get out the next twenty-five per cent. may perhaps not take much longer additional time than to abstract the first fifty per cent.; but the refractory quality in the oxygen keeps rapidly rising until it becomes practically almost a matter of impossibility to get out the last remnant of it. Ignorance of this simple law has kept many a sanguine inventor pursuing an *ignis fatuus*, and at its door must be laid the corpse of many a once cherished, but now lifeless "process."

From it arises the talk, sometimes so freely indulged in, about iron-sponge as a well-known article, quite at command if wanted.

As a curiosity in this line, let me quote from an English patent of 1870, taken out by a practical manufacturer, a manager of steel works : "The reduction of the ore to the condition of spongy metallic iron is a matter of comparatively little difficulty, and may be effected in various ways," etc.

These so-called iron-sponges carrying, say ten per cent. of the iron as protoxide, are not the materials with which to obtain a victory over the old, well-established, indirect process. They will give too poor an account in yield, however used, and they are especially objectionable for open-hearth practice. Dr. Siemens covers the whole ground in a few words, in his American patent of April 11th, 1871 : "The metallic oxide corrodes the banks of the metal bath."

Let us turn now to the second step in the direct process, the fusion of the iron-sponge. I will pass by all other methods of treatment and confine myself to this, the most important. The open-hearth gas-furnace enables us to produce a homogenous product cast into ingots. We will not stop here to discuss the various definitions of "steel" as distinguished from "iron." For present purposes we will adopt the popular conception, and apply the term steel to what a blacksmith would call steel, that is, whatever will "take a temper," and iron shall mean what the blacksmith would call iron; that is, what will stand the same heat and weld the same way as that which he has always called iron, and which will not take a temper.

These ingots of iron or steel (according to the ratio of carbon contained) are produced by melting wrought iron in cast iron. Here then is an operation for which the sponge is especially adapted.

It is more fusible than any other form of wrought iron, and its mineral portion will be separated by the act of fusion without any special treatment whatever.

I had no other idea than to use the "Siemens" regenerative gas-furnace (that being the one invariably employed heretofore in open-hearth practice) until I came to arrange for a license, when I was informed by the agents in this country of Dr. Siemens, that my license must contain the stipulation that I could only employ in the furnace such materials as he (Dr. Siemens) would permit me to use ; and my iron-sponge was not embraced in the list. After repeated efforts I found it impossible to shake his determination that his furnace should not be employed for any other direct process than his own. I was, therefore, obliged to look elsewhere, and, happily, found what I sought in the gas-furnace of Mr. H. Frank, of Pittsburg.

This furnace works on a system of "continuous regeneration," the waste gases passing continuously in one direction outward, and the air and gas supply passing continuously in one direction inward. I regret that the length of this paper compels me to omit a detailed description of this most satisfactory furnace. It gives all the heat that can be used (the endurance of the structure being the limit), and works with the greatest steadiness. All clogging of the regenerators by tar and soot is avoided by the simple expedient of alternating the currents of gas and air so that the air is made to pass through the chamber where the gas had previously been, thus burning out all those deposits, while the gas finds a clear passage in the other chamber where the air had been flowing. It is only neccessary to make this alternation between heats, so that, from the time of charging until the cast is made, the only manipulation called for is the adjustment of the inlet-valves for gas and air, and of the damper of the stack.

Our present practice at Glenwood is to take the iron-sponge and press it, while cold, into blooms of six inches diameter and about twelve to eighteen inches in length. A specimen of these is exhibited here. The pressing is performed by hydraulic machinery, and the force exerted is about 30,000 pounds to the square inch, or about 900,000 on the bloom. Thus prepared, we charge them into an auxiliary heating-furnace, where they are brought to a bright-red heat, and then thrown into the bath of the melting-furnace. We use no other form of wrought iron whatever. Otherwise there is nothing peculiar in our operations, and everything goes on just as if we were melting ordinary blooms, except that the fusion is much more rapid. We have no difficulty whatever with the lining of the furnace, owing to the small amount of protoxide left in the sponge, there being decidedly less than is usually found in puddle-bar. It is here that the perfection of the reduction tells.

We have operated hitherto with ores so rich—Iron Mountain of Missouri, and Red Specular of Lake Superior—that we have no excess of slag. On the contrary, we generally find it expedient to throw in a little cinder from a previous cast. When using ores which carry so much earthy matter that the slag would be in excess, we shall "bleed" it away, to the extent desired, from a cinder-notch which we have provided in the wall of the furnace.

I propose to do away with pig-iron, at first in part, finally altogether. There are two ways of doing this, both of which I shall practice long enough to determine which seems preferable, and hope to have the pleasure, on some future occasion, of reporting the results to you.

In the first method I avail myself of the system of rapid carburization practiced in "case-hardening" and in the melting of wrought iron in crucibles, viz., the employment of an accelerating agent, such as cyanogen, along with common carbonaceous material. Mixing one or more of these agents with charcoal-dust, and the resultant mixture again with sponge before pressing, I have a bloom which holds the carburizing materials in intimate contact with the particles of iron, and it is a question to be developed by experience what amount of carbon can be imparted to the iron up to the time of its fusion.

In the second method I take up Gurlt's idea of the carburization of sponge by hydrocarbon vapors, and apply it to my reducing furnace in this way: I have tapped a gas-pipe into one of the cylinders, so as to furnish an inlet by which I can force gas into and among the contents of the cylinder. This inlet is placed just above the cooler, so that the gas will enter when the material is yet hot, but has passed below the zone of reduction. I generate gas from benzine, in an apparatus placed at such a distance from the building as to be safe, and under pressure sufficient to overcome the resistance in the cylinder. I shall thus get the carburizing action without any other extra expenditure of fuel than the small amount required for generating the benzine gas. The apparatus is now just ready to go into operation, and I expect to impart such a quantity of carbon to the sponge as to render it readily fusible without the aid of a bath of cast iron.

I consider it a very desirable step in the perfecting of the direct process, that we should dispense with cast iron in the open hearth for two cogent reasons: first, because we have now turned the tables, and wrought iron is cheaper than pig; and second, because the less pig we use the better the quality of the product. Dr. Siemens, in the paper from which I have already quoted, puts this matter in a very clear light. Speaking of the desirability of a direct process, as regards the question of quality, and referring to one of Mr. I. Lowthian Bell's diagrams of a blast-furnace, he says:

"It shows that the reduction of the metallic oxydes to spongy iron is accomplished within the first twenty feet in their descent in the furnace, and at a comparatively low temperature. This upper zone is followed by one where the limestone is decomposed and the carbonization of the spongy metal is commenced. Between this second zone and the zone of fusion in the boshes of the furnace, one of great magnitude intervenes, where apparently no other change is effected than an increase of temperature of (the) spongy metal, but where in reality a very powerful reducing action

is accomplished of substances which had much better not be joined to the iron. It is well known that almost all the phosphorus contained in the ironstone and the coke is here incorporated with the spongy iron. The silica is reduced to silicon, and, together with arsenic and other bases which may be present, combines with the iron. The final action in the blast-furnace only consists in fusing those reduced substances and forming the slags which envelop and protect the fused metal."

On the other hand, as I have already explained, the low temperature at which the reduction of the iron oxyde takes place in the direct process gives no opportunity for reduction of the other oxydes accompanying it. Hence, though the mechanical union remains, there is no chemical affinity, and as we, in our second step, produce the fusion under conditions which do not allow time for the reduction of the other substances, we get away our iron uncontaminated.

Here, again, I have to regret that time and your endurance do not allow me to do more than refer to some exceptions to this, in the case of sulphur and phosphorus. As to the former, it is perhaps unnecessary for me to explain how the difficulty can be overcome. As to the latter, I will say, speaking from absolute experience, that no difficulty arises where the phosphorus exists—as in the Lake Champlain ores—in the condition of phosphate of lime. With respect to other phosphorus-bearing ores, I hope to make a special report to you, when I can enter into details which are inadmissible here, and after I have more extended experience. I must also defer anything beyond a mere casual reference to titanium, which gives no trouble in the direct process.

Dismissing these interesting topics, I close my explanatory statements, trusting that nothing further is needed to satisfy you that you have now presented to you a perfectly practical and thoroughly direct process for obtaining the ingot of cast steel or homogeneous iron.

Little need be said as to the value of this product. Open-hearth practice has already established the fact that steel fit for all purposes short of edge tools can be produced (even when using the system of melting wrought into cast iron), and that the homogeneous metal is the type of all perfection in wrought iron. With respect to the results which will follow the introduction of the direct process into the field of iron metallurgy, I do not venture any prediction as to how speedy or how slow may be the revolution. Some time must elapse, during which the old system will regulate the market price, while the new system will (for those employing it) regulate the cost. But with such data as I will now very briefly call your attention to, it is easy to see that the old system must either be greatly cheapened, or it must, sooner or later, be overgrown by the new.

The direct process demands so much smaller an amount of fuel that the proper plan for realizing the most profitable results in practicing it will be to go to the mines, and there produce the sponge at least; in many cases the ingot also. The extreme simplicity of the plant required, and the ease with which the process can be conducted on a small scale, if desirable, also point to the mine as the proper locality for the works, up to, as I say, the sponge always, the ingot often.

Take, now, such a locality, where ore of 50 per cent. metallic iron is worth $4 per ton, and charcoal is worth 6 cents per bushel, We have:

2 tons ore at $4	$8 00
40 bushels charcoal, at 6 cts.	2 40
Gas producing fuel (wood) say.	1 00
Wages, say	3 00
1 ton iron in sponge	$14 40

Let us add $5.60 per ton for transportation to a manufacturing centre, making the cost of the sponge, say $20, delivered. Add $2 per ton for cold pressing.

One ton of ingots will cost about as follows:

$\frac{3}{4}$ ton cold-pressed blooms, $22.	$16 50
15 per cent. waste on the same.	2 48
$\frac{1}{4}$ ton Bessemer pig, at $45	11 25
$7\frac{1}{2}$ per cent. waste on the same.	84
Wages, per ton	5 00
Maintenance of furnace, &c.	2 50
Spiegeleisen, $\frac{1}{20}$th ton, at $70 per ton	3 50
$\frac{3}{4}$ ton fuel for producers, at $5 per ton	3 75
Cost of 2,240 lb. ingots	$45 82

Assuming that we shall be able to substitute carburized sponge for the Bessemer pig, we reduce this to about $38.50.

The figures must be varied to suit every different locality, and in those where ore is a high-priced commodity and fuel cheap, there will not be as great a difference in favor of the direct process as where those conditions are reversed ; but there will always be enough to give it an advantage that must tell eventually.

Finally, there is one aspect, at least, of this branch of the subject that must be gratifying to all. I refer to the humanitarian view. The word "puddling" finds no place in the direct process. No such exhausting, overtaxing labor is demanded in any of its operations, and, as it is the truly scientific method of iron metallurgy, so does it, in common with all true science, point to the ultimate reconcilement of capital and labor.

I desire, before closing, to take this opportunity to acknowledge my indebtedness to my associate and colaborer, Mr. Morrison Foster, of Pittsburgh, whose assistance, from the first inception of my experiments up to the present time, has been of the greatest value to me.

Prof Egleston desired to know how complete the reduction was, how much oxygen remained in the sponge, and how the impurities common to iron ores were eliminated. He said that in the paper just read there were some severe remarks on the crude condition of iron metallurgy, especially the blast-furnace process. He desired to say that the blame did not lie at the doors of scientific metallurgists in this country. It must be remembered that most of the experiments abroad had government aid for their experiments, and government furnaces at their disposal to practice on. For the last thirteen or fourteen years he had endeavored to make experiments on blast-furnace gases, but had never been able to overcome the prejudice of furnacemen to having holes made in the stack of the furnace. Prof. Egleston spoke of some investigations made by Director Jüngst, of Gleiwitz, on the temperatures at which ores begin to lose oxygen in the blast-furnace, and the temperatures at which reduction is complete. The temperature of incipient reduction is stated by Jungst to be much lower than is generally supposed. Regarding the elimination of sulphur from coal by washing and coking, Prof. Egleston spoke of the works of the Orleans Railway, at Aubin, in the South of France, which he had studied, where a refuse coal containing 12 per cent. of ash and iron pyrites in large quantities, in lumps from the size of a hickory-nut to fine grains, was worked so as to contain only 3 per cent. of ash and 0.5 per cent of sulphur.

Mr. Blair : We find 95 to 98 per cent. of the iron reduced. The impurities in the ore, as silica, alumina, lime, etc., are all contained in the sponge ; but when the sponge is introduced into the bath of molten pig metal, the earthy ingredients melt and rise to the surface in the form of slag. In rich ores the amount of slag is not enough to cover the molten metal, and slag is added as such. In poor ores the amount of slag may be too large, and provision is made in the cinder-notch for tapping it off. The height of this notch is raised or lowered by means of fire-brick, according to the height of metal in the furnace.

Mr. F. Firmstone asked Mr. Blair what became of the phosphorus in the ore in his process.

Mr. Blair : We have made steel in crucibles from sponge made from Lake Champlain ores, which contained a large amount of apatite, and found no phosphorus in the steel. The case might be different where the phosphorus was combined with the iron in the ore.

Mr. Raymond remarked that it might make considerable difference if the phosphorus was combined with manganese in the ore. He had heard of a case recently, in which Bessemer pig was said to have been made from an ore containing 0.58 per cent. of phosphorus, and at the same time considerable manganese. It may be that phosphate of manganese is reduced with great difficuly, or that manganese will tend to carry off the phosphorus in the slag. He would like to ask Mr. Blair what became of the carbonic oxyde escaping from his cylinders.

Mr. Blair : It is burned within the thimble to carbonic acid, and exerts no injurious influence on the workmen. He

had had a few quite serious cases of poisoning with carbonic oxyde arising from his gas-producers, and had invariably found ammonia (spirits of hartshorn), applied to the nostrils, a prompt and efficient redemy. When nausea is produced by inhaling carbonic oxyde, a few drops of the aromatic spirits of ammonia give relief.

Prof. B. Silliman said that the question of the influence of manganese in smelting ores containing phosphorus was an interesting, and, to a considerable extent, an unexplored field. He had in mind a case where a spiegeleisen, containing 11 per cent. of manganese, and 0.1 per cent. of phosphorus, was said to be made from a spathic ore containing but 0.5 per cent. manganese, and 0.6 per cent. phosphorus. He thought that this could only be explained by the addition of manganese in some form to the charge, and in this connection the unexpectedly small amount of phosphorus in the spiegel was suggestive.

Mr. E. B. Coxe: The subject of poisoning by carbonic oxyde is one of such great importance that I think that all possible publicity should be given to the antidotal effect of ammonia mentioned by Mr. Blair. I think it very probable that the "white damp" of the mines is carbonic oxyde, and its fatal effects are well known to miners.

Mr. E. C. Pechin: I have listened to the very able paper read by Mr. Blair with melancholy pleasure. As a humanitarian I am delighted, as a pig-metal manufacturer I am in the depths of despair. I am placed in a position which must appeal powerfully to your sympathies. A few weeks since I was blown up by physical force—to-day I am blown away by scientific investigation. All my beautiful plans for new furnaces must be stowed away with the inscription, "What might have been if it had'nt been for Blair." In behalf of the pig-iron makers of the United States, I appeal to Mr. Blair to follow the example of Dr. Siemens, to surround his process with such restrictions, and to charge such excessive royalties, that we may for this generation, at least, rather die by slow combustion than meet a violent and hasty death by carbonic oxyde.

Mr. Blair reminded Mr. Pechin that he had used the expression that the old process will be *overgrown*, not *overthrown*.

Dr. Hunt expressed his pleasure at the results obtained by Mr. Blair, whose works near Pittsburg he had an opportunity of visiting in November last. He felt a great interest in the question of iron-sponge, from the fact that he had been the friend of Adrian Chenot, who had, in 1855, works in operation on a considerable scale at Clichy-la-Garenne, near Paris, and had assisted him in some of his experiments just before his sudden and accidental death at the end of that year. Chenot died with many of his plans unrealized, leaving behind him no one fully competent to carry on his work. Dr. Hunt testified that, notwithstanding the difficulties encountered, Chenot did succeed, at least with the readily reducible and porus Spanish ores, in obtaining a complete reduction, as the regular daily manufacture from the sponge of cast steel, which he had personally overlooked and followed, sufficiently showed. The apparatus of Chenot was essentially that of Mr. Blair, but there were practical difficulties in the way of heating the column which have been overcome by the latter by means of his simple and ingenious initial heater, in which the gas wasted from the top of Chenot's furnace performs the work of heating the ore in the upper part of the cylinder; while by the happy device of using a mixture of charcoal in powder, instead of in lumps, the difficulty of preserving the reduced ore from the influence of the air below is resolved. By these additions to the furnace of Chenot, Blair has continued and perfected his work.

But the ready production of iron-sponge was but one part of the problem; its utilization was still more difficult. The conversion of the sponge into cast steel by cementation with oil, and fusion in a crucible, as practised at Clichy by Chenot, was, at best, but a slow and troublesome method; and the attempt to weld the sponge into blooms, as tried at Clichy, and afterwards practiced at Baracaldo, in Spain, was an expedient not easy of execution, and applicable only to very pure ores. The work of Chenot, of Gurlt, and of others, in making iron-sponge, was in vain; the time had not yet come for its economic utili-

zation, nor was it until the brothers Martin, with the aid of the Siemens gas-furnace, succeeded in producing steel on a large scale in the open hearth from the fusion of soft iron with cast iron, that the true use of the sponge, as a substitute for puddled iron, was found.

This new process again turned the attention of inventors to the production of iron-sponge, and three or four years since a reduction-furnace, erected for the purpose at Westport, on Lake Champlain, succeeded in producing sponge which, at the Bay State Works, at South Boston, gave in the Siemens-Martin process a soft steel, with excellent results. This reduction-furnace, which the speaker had examined, seemed, however, but indifferently fitted for its work, and was soon abandoned. The simple, cheap, and efficient apparatus of Chenot has, in the hands of Mr. Blair, received such improvements as made it, in the speaker's opinion, admirably fitted for the purpose of reducing iron ores to sponge. He regretted exceedingly that the beautiful and ingenious reduction-furnace constructed by Mr. Edward Cooper, at Trenton, which many of the members of the Institute had an opportunity of inspecting in October last, was not already in operation, so that we might be enabled to judge of its practical efficiency. For the rest, the speaker entertained no doubt that the economic production of iron-sponge, and its utilization in the open hearth, in accordance with the Siemens-Martin plan, was destined to be one of the great metallurgical problems of the future. One of the most important advantages of this process is the fact pointed out by Mr. Blair, that the mechanical impurities of the reduced ore are readily and completely eliminated by the process of dissolving it in a bath of molten metal. The iron is reduced to the metallic state without the reduction of phosphorus and silicon, and the compounds of these are not attacked by the metallic bath, which takes up the reduced iron as mercury takes up the precious metals in the process of amalgamation.

EFFECTS OF STRESS ON INDUCTIVE MAGNETISM IN SOFT IRON.

By Prof. Sir WILLIAM THOMSON, F. R. S.

Proceedings of the Royal Society.

1. At the last ordinary meeting of the Royal Society (May 27), after fully describing experiments by which I had found certain remarkable effects of stress on inductive and retained magnetism in steel and soft iron, I briefly referred to seeming anomalies presented by soft iron which had much perplexed me since the 23d of December. Differences presented by the different specimens of soft iron wire which I tried complicated the question very much ; but one of them, the softest of all, a wire specially made by Messrs. Richard Johnson & Nephew, of Manchester, for this investigation, through the kindness of Mr. William H. Johnson, gave a result standing clearly out from the general confusion, and pointing the way to further experiments, by which, within the fortnight which has intervened since my former communication, I have arrived at a complete explanation of all that had formerly seemed anomalous. These experiments have been performed in the Physical Laboratory of the University of Glasgow by Mr. Andrew Gray and Mr. Thomas Gray, according to instructions which, in my absence, I have sent from day to day by post and telegraph.

2. The guiding result (described near the end of my former paper, and referred to in the last paragraph but one of the Abstract in Proceedings of the Royal Society for May 27) was, that the softest wire, tried with weights on and off repeatedly, after it had been magnetized in either direction by making the current, in the positive or negative direction, and stopping it, gave effects on the ballistic galvanometer which proved a shaking out of residual magnetism by the first two or three ons and offs, and a gradual settlement into a condition in

which the effect of "on" was an *augmentation*, and the effect of "off" a diminution, of the inductive magnetization due to the vertical component of the earth's magnetizing force. When a fresh piece of the same wire was put into the apparatus and tested with weights on and off it gave this same effect. If the wire had been turned upper end down and tried again in the course of any of the experiments, still this same effect would have been shown. It seemed perfectly clear that in these experiments there was no other efficient dipolar quality of the apparatus by which the positive throw of the ballistic galvanometer could be given by putting on the weight, and the negative throw by taking it off, than the vertical component of the earth's magnetic force.

3. Yet I did not consider that I had *explained* the result by the terrestrial influence, because, for *all* the specimens of steel and soft iron, the effect of weights on had been uniformly to *diminish*, and of weights off to *augment* the magnetism when the magnetizing current was kept flowing. And I was, moreover, perplexed by the magnitude of the result—the effects of weights on and off shown by the very soft iron wire, under only the feeble magnetizing influence of the earth, being many times (from three times to nine or ten times) as great as the effects which the same weights on and off produced in the same wires when under vastly greater magnetizing forces of the currents through the helix.

4. But by reducing the strength of the magnetizing current gradually, it was clear that the small positive effect of the "on" with the positive current flowing and the small negative effect with the negative current must be gradually brought to approximate more and more nearly to the large positive effect of the "on" when there is no current at all. Immediately after my former communication I therefore arranged to have experiments made with different measured strengths of current, feebler and feebler, until the law of the continuity thus pointed out should be ascertained; and so speedily arrived at the following astonishing conclusions:

5. (1) When the magnetizing force does not exceed a certain critical value the alternate effects of *pull* and *relaxation* are respectively to augment and diminish the induced magnetization.

(2) When the magnetizing force exceeds the critical value the effects are—pull diminishes, relaxation augments, the induced magnetization.

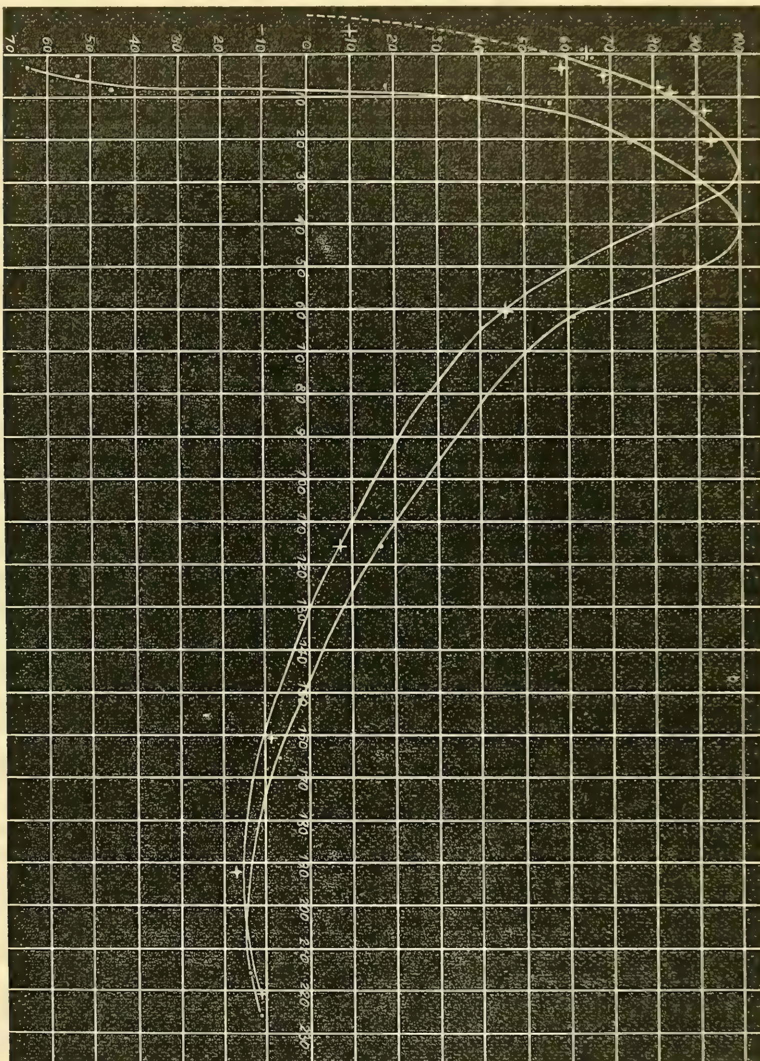
(3) The critical value of the magnetizing force for the annealed Johnson soft iron wire, with 14 lbs. on and off, is about 17 or 18, if (for a moment) we take as unity the vertical component of the terrestrial magnetic force at Glasgow.

(4) The maximum positive effect of the pull on the inductive magnetism is obtained when the magnetizing force is about 4.

(5) The positive effect of the pull when the magnetizing force is 3 is about eight or nine times the amount of the negative effect when the magnetizing force is 25.

6. The actual results of the experiments which proved these conclusions are exhibited graphically in the accompanying diagram. The hotizontal scale (abscissas) shows the numbers of divisions of the scale of the steady current galvanometer (called for brevity the "battery-galvanometer") used to measure the strengths of the current through the helix. The scale of ordinates shows the numbers of divisions of the scale of the ballistic galvanometer by which the sudden changes of the magnetism of the wire produced by 14 lbs. "on" and 14 lbs. "off" were measured. The ordinates are drawn in the positive direction when the effect of "on" is to increase and of "off" to diminish the magnetism. The simple round spots show the results of observations with currents in the direction called negative (being those which gave negative deflections of the battery-galvanometer). The spots in the centre of signs (+) show results obtained with currents in the direction called positive. The star (*) at the position 64 on the line of ordinates through the zero of abscissas shows the mean effect of many ons and offs with no current flowing—that is to say, when the sole magnetizing force is the vertical component of the earth's magnetic force. The curves are drawn as smoothly as may be by hand, one of them to pass as nearly as it can (without intolerable roughness) through all the crossed (plus) dots and

the star at 64, the other through all the plain dots. The latter curve cuts the line of abscissas at 8, this being the result (telegraphed to me this evening) of special experiments made to-day for the purpose of finding accurately the amount of the negative current which, by neutralizing the vertical force of the earth or the wire, gives an accurate zero effect for the "off" and "on." The dotted prolongation of the curve through the plus's, to cut the line of abscissas on its



negative side, is ideal, and is inserted to illustrate the relation of this curve to the other. By the two curves cutting the line of abscissas at + 8 and — 8, we see that 8 is the strength of the current, measured on the scale of the battery-galvanometer, which gives a magnetic force in the axis of the helix equal to the vertical component of the terrestrial magnetic force.

7. Next a series of experiments to test the inductive effects of repeatedly making the current always in one direction, and stopping it, with the weight of 14

lbs. always on, and again with the weight off, and this with various degrees of current, feebler than those used in the earlier experiments. The results with all the different intensities of magnetizing force thus applied were the same in kind as that which I found on the 23d of December, operating with a much stronger magnetizing force on the first soft iron wire tried; that is to say (contrarily to what I had found in the steel wires), *the change of magnetization produced by repeated applications and annulings of the magnetizing force of the helix was greater with the weight off than on.*

[*Note on Diagram, added July* 2, 1875. —A continuation of the experiments with higher and higher magnetizing powers, since the communication of this paper, disproves the negative minimum indicated by the curves on the diagram, and proves an asymptotic approach to a value approximately — 12, of ordinates for infinitely great positive values of the abscissas.]

THE HYDRAULIC DOUBLE FLOAT.

By HENRY L. ABBOT, Major of Engineers, Brevet Brigadier General.

Written for VAN NOSTRAND'S MAGAZINE.

In the August number of this Magazine appeared an article by Prof. S. W. Robinson, on River Gauging and the Double Float.

As he refers therein to some observations made with the latter upon the Mississippi Delta Survey, I will very briefly correct a few misapprehensions into which he has fallen.

Some are of little importance; as, for instance, when he states that the double float was used upon "the Mississippi, previous to the Delta Survey, by Mr. Chas. Ellet. This is an entire mistake, as Mr. Ellet's first trial of them was made after they had come into regular daily use by the parties of the Delta Survey.

Prof. Robinson argues that the current meter in some form must be superior to the double float, because it has been adopted more generally by hydraulic engineers — and he establishes the fact of more general use by citing the names of many engineers whose observations were made with it. If the dates of most of the measurements had been given, it would have been at once apparent, that, although suggested long ago, the double float as now used is really the more modern instrument of the two. The flint lock musket has been employed far more in great battles than the modern breech loader, but its superiority is not established thereby.

It would seem that the fairer criterion of the merits of the two instruments, would be the practical results obtained from their use. Now, it is certain that, although many careful observers employed time and money, and displayed great scientific ability in endeavoring to discover the law of change in velocity from surface to bottom by the use of meters, they utterly failed to detect the form of the curve. Whereas, on the very first serious attempt with the double float, a law was revealed which has since received many confirmations, and which has greatly simplified the operation of the practical gauging of rivers by showing, first algebraically and afterward by actual trial, that the ratio of the mid depth to the mean velocity is practically constant, and is even unaffected by the wind. The scientific Engineer Corps of India has recognized the value of the modern form of the instrument, and is now extensively applying it in their operations upon the great rivers of that country. The latest and most accurate work in river gauging done in this country since the date of the Delta Survey—I refer to the unpublished material of the Connecticut River Survey conducted by General Ellis, which will appear in the forthcoming report of the Chief of Engineers U. S. Army—establishes the facts that the double float and meter, properly used, give sensibly the same result; and that the fundamental law respecting flowing

water announced in the Delta Report for the Mississippi River, is true also for the Connecticut. So far then as the useful record of the two classes of instruments is concerned, the double float is no whit behind.

Prof. Robinson fails to touch upon the great practical objection to meters—namely the uncertainty which attends the determination of the coefficient for translating their revolutions into feet per second. So long as it remains impossible to exactly reproduce the same identical conditions in deducing this coefficient, which are to affect the observations themselves, so long will there be grounds for doubt and uncertainty in this vitally important point. Therefore, without disputing the value of the instrument for certain kinds of work, its superiority to the double float for detecting slight changes in velocity may well be doubted.

Without following Prof. Robinson in his application of the higher mathematics to the theoretical solution of the problem of the mutual influence of the several parts of the double float upon each other ; I would like to suggest one or two ideas.

He treats the problem upon the assumption that the curve of velocity from the surface to the bottom of a river, is unvarying. Now all observations show that a continual irregular pulsation is going on ; and that the mean curve is only to be deduced from many observations. Hence the different parts of the double float are acted upon by varying forces ; and thus their *masses* cannot be neglected, as he has done, in treating the subject. In other words, there is a continual gain or loss of living force in the several parts which will prevent the large and heavy sub-float from being affected as his equations indicate.

Whatever may be the value of these equations for other rivers, we are not left in doubt as to their entire inapplicability to the Mississippi River, at least as he has applied them. This truth does not rest upon any theory, but upon a fact observed again and again, and recorded in the note books of the Survey. To make this clear a few words are necessary.

No matter how deep the river, we found that, if the lower float touched bottom, the sudden check in velocity gave an unmistakable oscillation to the surface float. The points of crossing the transit lines, two hundred feet apart, were both fixed accurately by triangulation ; and the telescope of one or other of the observers was kept on the little flag during the whole of the critical period of its motion. The exact soundings in the vicinity, and the daily gauge records, rendered it possible to know precisely the depth of water in every part of the path of the float. Now it was sometimes the case that a float would diverge a little, laterally, into water too shoal for its length of line—and in such cases it at once revealed the fact by the bobbing of the flag—which was duly noted in the record book. We have, therefore, certain knowledge that in many cases, and probably in all, our deep floats preserved the depths at which they are reported. Prof. Robinson's diagrams and imputations, therefore, evidently do not apply to the work of the Delta Survey.

I have only one more remark to add ; Prof. Robinson lays much stress on our neglect to reduce the size of the connecting cord—and suggests, in its place, a wire filament, a hundredth of an inch in diameter. The importance of using cords of the minimum size was perfectly appreciated ; and, on the only occasion during the Survey when it was practicable to use a fine wire to advantage, viz. on the Little Falls Feeder of the C. and O. Canal, reported on page 252 of the report, such a wire was actually used—probably for the first time in the history of the double float. The reason why, in our deep measurements on the Mississippi, we used so large a cord, was because it was found by experience to be necessary. The cord, in raising the float, had at times to sustain severe strains, amounting to fifty or more pounds ; and smaller cords had not the requisite strength. The operation of gauging the Mississippi in flood was a struggle—not a delicate laboratory task. The whirl of the waters, which six oars vigorously plied in a light skiff could hardly stem ; the rushing drift-logs, which at the peril of life must be avoided ; the passing steamers that often seemed to enjoy interrupting our work ; and, lastly, the importance of multiply-

ing observations as rapidly as possible, in order to keep the finger firmly upon the pulse of the great river—all compelled the use of apparatus which would endure rough handling without breaking.

In conclusion, I would express the hope that nothing in the foregoing communication may seem to imply any desire on my part to undervalue the interesting article of Prof. Robinson, which opens a new subject for analytical investigation. I only wish to show that, in applying his formulæ to the Mississippi Delta Survey observations, he was not informed as to all the circumstances in the case.

ON THE THEORY OF VENTILATION—AN ATTEMPT TO ESTABLISH A POSITIVE BASIS FOR THE CALCULATION OF THE AMOUNT OF FRESH AIR REQUIRED FOR AN INHABITED AIR SPACE.

By Surgeon-Major F. DE CHAUMONT, M. D.

From the Proceedings of the Royal Society.

The question of ventilation, and the amount of fresh air required to keep an inhabited air-space in a sweet and healthy condition, has been much discussed of late years, and very fully treated of by various writers ; but there was a good deal of vagueness and want of precision in the manner of treatment previous to the Report of the Committee on Metropolitan Workhouse Infirmaries in 1867. In a paper in the 'Lancet' in 1866 I attempted to show that a more scientific method might be employed, and suggested some formulæ, which we quoted by Dr. Parkes in a paper appended to the Report above mentioned. Professor Donkin also investigated the question there, and in a short but exhaustive paper showed that, general diffusion in an air-space being admitted, the same amount of air was required to ventilate it, whatever its size might be. In another paper, published in the 'Edinburgh Medical Journal' in May 1867, I went into the subject with the view of pointing out that we might, with existing data, establish a basis, which should be both scientific and practical, for estimating the amount of air required ; and I adduced some results to show that the evidence of the senses might be employed (if used with proper care and precautions) as the ground-work of a scale, and gave a short table of the amounts of respiratory impurity (estimated as CO_2) which corresponded to certain conditions noted as affecting the sense of smell. This paper attracted the attention of General Morin, who made it the text of a short article in the Journal of the Conservatoire des Arts et Métires during last year. Since the publication of my paper in 1867 I have accumulated more data ; and the number of observations being now sufficient to give at least a fair approximation to the truth, I beg to call attention to the results.

It is generally admitted that it is organic matter, either suspended or in the form of vapor, that is the poison in air rendered impure by the products of respiration. It is also admitted that it is the same substance that gives the disagreeable sensation described as "closeness" in an ill-ventilated air-space. Although the nature of the organic matter may vary to a certain extent, it will be allowed that a condition of good ventilation may be established if we dilute the air sufficiently with fresh air, so that the amount of organic matter shall not vary *sensibly* from that of the external air. Unfortunately all the methods devised for the determination of organic matter in air are both difficult and unsatisfactory, so much so that they are almost practically impossible in a ventilation inquiry. Observations, however, as far as they have gone, seems to show that the amount of organic impurity bears a fairly regular proportion to the amount of carbonic acid evolved by the inhabitant in an air-space ; and as the

latter can be easily and certainly determined, we may take it as a *measure* of the condition of the air-space. This being accepted, and general diffusion being admitted, we can easily calculate the amount of fresh air required to bring down the CO_2 to some fixed *standard*, adopting as a datum the ascertained average amount of CO_2 evolved by an adult in a given time. If, now, we adopt as our *standard* the point at which there is no sensible difference between the air of an inhabited space and the external air, and agree that this shall be determined by the effects on the sense of *smell*, our next step is to *ascertain* from experiment what is the average amount of CO_2 in such an air-space, from which we can then calculate the amount of air required to keep it in that condition. The sense of smell is very quickly dulled, so that, in order to keep it acute, each air-space to be examined ought to be entered directly from the open air. For this reason I have not included in the present paper any of the observations made in prisons, as it is almost impossible, from their construction, to enter the cells directly from the open air. All the results, therefore, have been obtained in buildings where this could be done, viz. barracks and hospitals, and several were examined.

The plan followed in all was to take the observations chiefly at night, when the rooms or wards were occupied, and when fires and lights (except the lamp or candle used for the observation) were out. In this way all disturbing sources of CO_2 were avoided, except in the occasional rare instances of a man smoking in bed or the like. On first entering the room from the outer air the sensation was noted and recorded just as it occurred to the observer, such terms as "fresh," "fair," "not close," "close," "very close, "extremely close," &c. being employed.* Most of these notes were made by myself ; but a good many were also made by my assistants, Sergt. (now Lieut.) Sylvester in the eariler, and Sergt. H.Turner in the latter experiments. The air was then collected (generally in two jars or bottles, for controlling experiments), and set aside with lime-water for subsequent analysis, and the temperatures of the wet- and dry-bulb thermometers noted. About the same time samples of the external air were also taken, and the thermometers read. In this way any unintentional bias in the record of sensations was avoided, and this source of fallacy fairly well eliminated.

In some of the earlier observations the CO_2 in the external air was not observed as constantly in connection with the internal observations, partly because the importance of this was not so clearly perceived then, and partly from want of apparatus, the jars used being very bulky and not easy of carriage. It might therefore be argued that the *combination-weights* of the earlier experiments should be less in calculating the averages. I do not think, however, that this would amount to any sensible difference in the result, as the external CO_2 ratios adopted from single experiments accord fairly with the mean ratio of the outer air*. In each case the CO_2 has been corrected for *temperature*, but not *for barometric pressure*, and in some cases the reading of the barometer was not taken ; the difference, however, would not exceed on an average 1 per cent. The vapor and humidity were calculated from Glaisher's Tables.

Although the records of sensation are various in terms, I have thought that they might be advantageously reduced to *five* orders or classes, as follows :

No. 1. Including such expressions as "fresh," "fair," "not close," "no unpleasant smell," &c., indicating a condition giving no appreciably different sensation from the outer air.

No. 2. Including such expressions as "rather close," "a little close," "not very foul," "a little smell," &c., indicating the point at which organic matter begins to be appreciated by the sense of smell.

No. 3. "Close," indicating the point at which organic matter begins to be decidedly disagreeable to the sense of smell.

No. 4. "Very close," "bad," &c., indicating the point at which or-

* N. B. The terms used in the Tables are *exactly* those noted down at the time of observation.

* Mean ratio of the whole series .372 ; omitting those at Portsmouth Garrison Hospital, which were exceptionally low, 413.

ganic matter begins to be offensive and oppressive to the senses.

No. 5. "Extremely close," "very bad," &c., indicating the point at which the maximum point of differentiation by the senses is reached.

Where there was a slight smell of tobacco no change in the record was made; but where the smell of tobacco was strong, the observation was generally referred to the next order, both because the presence of the tobacco-smoke indicated slow change of atmosphere, and also because the sense of closeness must have been considerable to make itself felt along with the tobacco. Hence such a remark as "rather close," which properly belongs to No. 2, is referred to No. 3, "close," if accompanied with a strong smell of tobacco.

The total number of observations for the temperature, vapor, and humidity in the inhabited spaces amounts to 247*, and of carbonic-acid analyses to 473. Where the latter are in pairs they are linked by a bracket. In each case the external and internal observations and their differences are given, and the arithmetical means of all are taken. In the differences which represent the quantities due to respiratory impurity, the mean error, error of mean square, and probable error (both of a single measure and of the result) are calculated, and the limits shown between which the range would lie in each case. The values are also given as the reciprocals of the squares of mean error and of probable error of result, and their ratios to No. 1 as unity. The modulus is also calculated from the mean error and error of mean square, and the ratio of the two resuls thus obtained shown as another means of estimating the value of the series.

Analyses of the different Orders.

No. 1. "Fresh," &c.: a condition of atmosphere not *sensibly* different from the external air.

1. *Temperature.*—The experiments were made during both winter and summer, so that there is a good deal of variation in the external temperature, and the mean is some degrees above the mean annual temperature of this country (southern part of it), viz. 57°.47. The mean in the inhabited air-spaces is 62°.-85, or 5°.38 higher. This is a moderate difference, and shows a good average temperature for dwelling-rooms. The maximum range is 10° (57°.89 to 67°.-81), calculated from the error of mean square, the actual extremes being 77° and 53°.

2. *Vapor and Humidity.*—As the external temperature varied considerably, so also did the amount of vapor, the mean being 4.285, equal to about 80 per cent. of humidity. The internal observations showed a mean of 4.629, or 73 per cent. of humidity, being an excess of vapor of 0.344 of a grain, and a lowering of relative humidity equal to 7 per cent.

3. *Carbonic Acid.*—The mean external carbonic acid was 0.4168, a little above the usual amount. The mean in the inhabited air-spaces was 0.5998, or an excess of 0.1830, the mean error being 0.0910. The probable error of a single observation is 0.0831, so that the truth would lie between 0.2661 and 0.0999; whilst the probable error of the result is only 0.0078, the range being between 0.1908 and 0.1752; we are therefore entitled to say that the limit of impurity, imperceptible to the sense of smell, lies at or within 0.2000 volume of CO_2 per 1000 as a mean. From these data, then, we may lay down as conditions of *good* ventilation the following:

Temperature about 63° Fahrenheit.

Vapor shall not exceed 4.7 grains per cubic foot.

Carbonic acid shall not exceed the amount in the outer air by more than 0.2000 per 1000 volumes.

No. 2. "Rather close" &c.: a condition of atmosphere in which the organic matter begins to be appreciated by the senses.

1. *Temperature.*—In this series the external temperature (although still above the mean temperature of this climate) was rather lower than in the previous one, viz. 54°.85, whilst the internal observations gave a mean of 62°.85 (the same as in No. 1), or a difference of 8°.

2. *Vapor and Humidity.*—Although the temperature was the same as in No. 1, the amount of vapor in the inhabited air-spaces was greater, both actually and

* It has been thought unnecessary to give these in detail as taking up too much space, but the means are given at the end of the Table of Carbonic Acid.

relatively, the excess being 0.687 of a grain and the lowering of humidity being about 7.6 per cent.

3. *Carbonic Acid.*—The mean amount in the outer was 0.4110 per 1000 volumes, in the inhabited air-spaces 0.8004, or a mean difference (respiratory impurity) of 0.3894. The range for the probable error of result lies between 0.4057 and 0.3731.

We may therefore say that ventilation ceases to be *good* when the following conditions are present :

Vapor in the air exceeds 4.7 grains per cubic foot.
CO_2 in excess over outer air, ratio reaching 0.4000 per 1000 volumes.

No. 3. "Close" &c.: the point at which the organic matter begins to be decidedly disagreeable to the senses.

1. *Temperature.*—The temperature in this series was more near the mean of our climate, viz. 51°.28. The mean in the inhabited air-space was 64°.67, or a mean excess of 12°.91.

2. *Vapor and Humidity.*—The vapor in the outer air was 3.837, and in the inhabited air-space 4.909, a mean difference of 1.072 grain per cubic foot. The drying of the air amounted to a lowering of the humidity by 11.56 per cent.

3. *Carbonic Acid.*—The carbonic acid in the outer air was 0.3705 per 1000 volumes, rather below the average. In the inhabited air-spaces it was 1.0027, or a mean difference of 0.6332 due to respiratory impurity, the range for the probable error of result being between 0.647 and 0.617.

We may therefore say that ventilation begins to be decidedly *bad* when the following conditions are reached :

Vapor reaches 4.9 grains per cubic foot.
Carbonic acid in excess over outer air to the amount of 0.6000 per 1000 volumes.

No. 4. "Very close," &c. : the point at which the organic matter begins to be offensive and oppressive to the senses.

1. *Temperature.*—The mean external temperature was 51°.28, and the internal 65°.15, or a mean difference of 13°.87.

2. *Vapor and Humidity.*—The mean vapor in the outer air was 3.678 grains, and in the inhabited air-spaces 5.078, or a mean difference of 1.400 grain per cubic foot. This corresponds to a lowering of the humidity by 8°.58 per cent.

3. *Carbonic Acid.*—The mean amount in the outer air was 0.3903 per 1000 volumes, pretty near the usual average. In the inhabited air-spaces it was 1.2335, or a mean difference due to respiratory impurity of 0.8432, the range for probable error of result being between 0.8640 and 0.8224.

We may say that ventilation is *very bad* when :

Vapor reaches 5 grains per cubic foot.
Carbonic acid in excess over outer air reaches 0.8000 per 1000 volumes.

No. 5. "Extremely close," &c. : the maximum point of differentiation by the senses.

1. *Temperature.*—The temperature in the outer air was 51°.86, and in the inhabited air-spaces 65°.05, giving a mean difference of 13°.19.

2. *Vapor and Humidity.*—The mean vapor in the outer air was 3.875, and in the inhabited air-spaces 5.194, showing an excess of 1.319 grain, corresponding to a lowering of relative humidity of 9.88 per cent.

3. *Carbonic Acid.*—The mean amount in the outer air was 0.4001, or exactly the average amount. In the inhabited air-spaces it was 1.2818, showing an excess due to respiratory impurity of 0.8817 per 1000 volumes, the range for the probable error of result being between 0.9202 and 0.8432.

The extreme point of differentiation by the senses is thus reached when the following conditions are found :

Vapor 5.100 grains per cubic feet.
Carbonic acid in excess over the amount in the outer air beyond 0.8500 per 1000 volumes.

It will at once be seen that the figures in No. 5 differ but little from those in Mo. 4, and that the probable *limit of differentiation* by the senses is reached in No. 4. The number of recorded observations in No. 5 is also very few compara-

tively; and I think it would therefore be better to group the two together, as below.

Nos. 4 and 5 combined, being the probable limit of possible differentiation by the senses.

1. *Temperature.* — In the outer air 51°.43, in the inhabited air-spaces 65°.12, or a mean difference of 13°.69.

2. *Vapor and Humidity.*—The vapor in the outer air was 3.729, inside 5.108, or a mean difference of 1.379 grain, corresponding to a lowering of relative humidity of 8.92 per cent.

3. *Carbonic Acid.*—In the outer air 0.3928, in the inhabited air-spaces 1.2461, or a mean difference to respiratory impurity of 0.8533, the range for probable error of result being between 0.8717 and 0.8349.

We may therefore, I think, say that when the vapor* reaches 5.100 grains per cubic foot, and the CO_2 in excess 0.8000 volume per 1000, the maximum point of differentiation by the senses is reached.

By referring to the Tables it will be seen that there is a regular progression as we pass from one order to another. The following abstract shows this:

No.	Temperature.		Vapor.		Carbonic Acid.	
	In air-space.	Excess over outer air.	In air-space.	Excess over outer air.	In air-space.	Excess over outer air.
1	° 62.85	° 5.38	4.629	0.344	0.5999	0.1830
2	62.85	8.00	4.823	0.687	0.8004	0.3894
3	64.67	12.91	4.909	1.072	1.0027	0.6322
4	65.15	13.87	5.078	1.400	1.2335	0.8432
5	65.05	13.19	5.194	1.319	1.2818	0.8817

The progression is complete in the carbonic acid, although there are slight retrogressions in the temperature and vapor of No. 5. Taking the last two combined, we have

65°.12 13°69 5.108 1.379

1.2461 0.8533

We have now the progression complete throughout. Adopting *four* orders, then, we shall find the regularity of progression sufficiently note-worthy in the *vapor* and *carbonic acid*, the two products of respiration. It is less regular in the temperature, as might indeed be expected, from the varying condition of the external air.

TABLE OF DIFFERENCES OF TEMPERATURE, VAPOR, AND CO_2.

No.	Temperature.		Vapor.		Carbonic Acid.	
	Actual excess over outer air.	Progressive difference.	Actual excess over outer air.	Progressive difference.	Actual excess over outer air.	Progressive difference.
1	° 5.38	° ..	0.344	..	0.1830	
2	8.00	2.62	0.687	0.343	0.3894	0.2064
3	12.91	4.91	1.072	0.385	0.6322	0.2428
4 and 5 (combined).	13.69	0.78	1.379	0.307	0.8533	0.2211

In each observation there is a culmination at No. 3, and a decline at the next

* It is to be understood that the amounts of vapor stated in these cases are in reference to a mean temperature of about 63° F.

order. The average rates of progression (including the actual excess in No. 1) are :

Temperature.	Vapor.	Carbonic Acid.
3°.42	0.345	0.2133

Here the amount of vapor is exactly the actual excess in No. 1, and the amount of carbonic acid somewhat in excess; the mean, however, between this amount and the actual recorded excess in No. 1 is as follows :

Actual excess over outer air in No. 1...	0.1830
Mean of progressive increase, as above.	0.2133
Sum..................	2)0.3963
Mean..................	0.1982

This is sufficiently close to 0.2000 to furnish some additional reason for adopting this latter number as the limit of respiratory impurity admissible in *good ventilation.*

Values of the several series, considered relatively to each other.

The values are important as a guide to the more or less trustworthy character of the series. They have been calculated out in three ways :

1. As the reciprocal of the square of *mean error.*
2. As the reciprocal of the square of probable error of result.
3. As the ratio between the *modulus* calculated from the *mean error* and the *modulus* calculated from *the error of mean square of a single measure.*

The following Table gives the values from the first method, viz. as reciprocal of the square of mean error :

No.	Temperature.	Vapor.	Humidity.	Carbonic Acid.
1	0.0821	6.1300	0.0190	122.0000
2	0.0625	3.1300	0.0140	34.0000
3	0.0403	2.6500	0.0110	21.8000
4	0.0543	2.7700	0.0120	17.0000
5	0.0664	1.3700	0.0090	14.1000
4 & 5 combined	0.0610	2.2900	0.0010	16.5000

And the ratios, taking No. 1 as 1000, are :

No.	Temperature.	Vapor.	Humidity.	Carbonic Acid.
1	1000	1000	1000	1000
2	760	510	735	277
3	492	431	575	178
4	662	450	630	139
5	810	224	473	115
4 & 5 combined	745	374	526	135

Here we see that there is a diminution of value pretty regular up to No. 3, when there is a rise in No. 4 and No. 5 in the temperature, a rise in No. 4 and a fall in No 5 in the vapor and humidity, whilst the fall is progressive throughout in the carbonic acid.

In each case the result of the combination of 4 and 5 gives a number which takes its proper place after No 3, except in the temperature.

The following Table give the values according to the second method, viz. as reciprocal of the square of the probable error of the result :

No.	Temperature.	Vapor.	Humidity.	Carbonic Acid.
1	5.2716	293.93000	1.2656	16378.2000
2	4.1165	324.2300	0.5318	3750.4000
3	3.7470	281.3300	1.0966	4148.1000
4	3.7100	170.000	0.5439	2307.5000
5	1.5839	34.2770	0.1986	674.3000
4 & 5 combined	5.3171	195.8300	0.7708	2957.5100

And the ratios, taking No. 1 as 1000, are :

No.	Temperature.	Vapor.	Humidity.	Carbonic Acid.
1	1000	1000	1000	1000
2	781	1103*	420	229
3	711	957	867	253
4	704	578	432	141
5	302	117	157	41
4 & 5 combined	1008*	667	609	181

Here we see much the same order preserved, except that in two cases marked * (*Nos.* 4 *and* 5, *temperature, and No.* 2, *vapor*) the amounts exceed No. 1. It is also observable that in the vapor, humidity, and carbonic acid No. 3. is superior to No. 2. In every case the combined 4 and 5 series is superior to the two singly, being nearly their sum. In all the Tables it may be observed that the humidity is somewhat irregular in relation to the amount of vapor. This may be understood from the fact that it is a complex quantity, depending partly on the amount of vapor, and partly on the temperature.

If we now seek to get a general expression of the relative values of all the observations in each *order*, we may take the product of their values by the different methods.

Table showing the Products of the Values of each Order, calculated from the Reciprocals of the Squares of Mean Errors.

No. of Order.	Product.	Ratio.
1	1.1720	1000
2	0.0931	794
3	0.0256	218
4	0.0307	262
5	0.0115	98
4 & 5	0.0230	196

Table showing the same from Probable Error of Result.

No. of Order.	Product.	Ratio.
1	32139057	1000.00
2	2661995	83.00
3	4794655	149.00
4	791570	25.00
5	7254	0.23
4 & 5	2373680	74.00

Here we see a greater irregularity, No. 3 showing a superiority over No. 2, due probably to the greater number of individual observations in the former case.

Taking the mean of the ratios by the two methods, we have :

No.			No.		
1	=	1000	4	=	144
2	=	439	5	=	49
3	=	184	4 & 5	=	135

But the discrepancy in the ratios of the values from the probable error, where No. 3 exceeds No. 2, is due to the irregularity in the humidity column ; and as this is not an independent quantity, but dependent on the temperature and vapor, we may legitimately omit it. We shall then have the products as follows :

Values from Mean Error.

No.	Value.	Ratio.
1	61.40	1000
2	6.65	108
3	2.33	38
4	2.56	41
5	1.28	21
4 & 5	2.30	38

Values from Probable Error of Result.

No.	Value.	Ratio.
1	25382435	1000.00
2	5005632	197.00
3	4372692	172.00
4	1455360	57.00
5	36526	1.44
4 & 5	3079500	121.00

It will be seen that in the calculation from mean error there is a rise at No. 4 in both instances, *i. e.* with and without the humidity. There is a fall at No. 5, whilst the combined series 4 and 5 gives a result which follows naturally after No. 3. We may now reject Nos. 4 and 5 as separate orders, and consider them in combination, when we shall have the following relative values:

No.	From Mean Error.	From probable Error of Result.
1	1000	1000
2	108	197
3	38	172
4 & 5	38	121

And the mean of the two values will be:

No. 1........1000 No. 3 108
No. 2........ 153 Nos. 4 & 5... 80

We have now a series of ratios which follow a regularly descending scale, very much in the order we might have expected *a priori*, seeing that the sense of smell is naturally less acute as the organic matter increases in amount. But it is of less consequence to determine the position of the higher orders in the scale, except as a measure of the general value of the observations throughout the inquiry, the really important point being the very great superiority of the first order, particularly as regards the carbonic acid. This is an additional argument for its adoption as the limit of admissible impurity in good ventilation.

The amount of fresh air necessary to keep the impurity down to the particular limit would be according to the following formula,

$$d=\frac{e}{q}$$

where d is the delivery of fresh air in cubic feet per head per hour, e the amount of carbonic acid expired per hour by one inmate, and q the limit of respiratory impurity taken as carbonic acid per cubic foot. If we take e to be the 0.6 of a cubic foot in a state of complete repose, such as during sleep, we are rather under Pettenkofer's estimate, but considerably above Angus Smith's. The following Table gives the amounts necessary for the three estimates:

No. of order.	Limit of respiratory impurity per cubic feet.	Cubic feet of air per head per hour calculated from		
		Angus Smith's estimate, $e=0.450$.	Proposed estimate as adopted by Dr. Parkes, $e=0.600$.	Pettenkofer's estimate, $e=0.705$.
1	0.0001831	2460	3280	3850
2	0.0003894	1155	1540	1810
3	0.0006322	710	950	1115
4 & 5	0.0008533	530	700	825

I think that the general opinion is that Angus Smith's results give too low an estimate, and that 0.600 is really the lowest that can be with safety admitted.

The existing Army Regulations contemplate a delivery of 1200 cubic feet per head per hour in barracks; but practical inquiry has shown that this amount is generally fallen short of. The result is that the life of the soldier, at least during his sleeping-hours, is passed in a No. 3 air-space, or one in which the organic impurity is *decidedly disagreeable to the senses.* Previous to 1858 he did not even get this moderate amount of air; so that his life was spent in an air-space in which the organic matter was *offensive and oppressive to the senses.* If we adopt (as proposed already) 0.2000 per 1000 of CO_2 as the limit of impurity, then 3000 cubic feet per head per hour is the amount which must be delivered, on the supposition that $e=0.600$, or 3525 if $e=0.705$.

We may say, in conclusion, that the experimental data already quoted fairly justify the adoption of the following conditions:

Conditions as to the Standard of good Ventilation.

Temperature (dry bulb) 63° to 65° F.
" (wet bulb) 58° to 61° F.

N. B.—The temperature should never be very much below 60°, but it may be found difficult to prevent its rising in hot weather. In any case the difference between the two thermometers ought not to be less than 4°, and ought not to exceed 5°.

Vapor ought not to exceed 4.7 grains per cubic foot at a temperature of 63 F., or 5 grains at a temperature of 65° F.

Humidity (per cent.) ought not to exceed 73 to 75.

Carbonic Acid.—Respiratory impurity ought not to exceed 0.0002 per foot, or 0.2000 per 1000 volumes.

Taking the mean external air ratio at 0.4000 per 1000, this would give a mean internal air ratio of 0.6000 per 1000 volumes.

By considering separately the conditions found in barracks and in hospitals, or among healthy and among sick men, a point of some interest and importance seems to be indicated—namely, that more air is required for the latter than for the former to keep the air-space pure to the senses. This is due either to the greater quantity of organic matter or to a difference in its quality and nature. The following results are found from the data in the Tables:

	Barracks.	Hospitals.
Mean amount of carbonic acid per 1000 volumes as respiratory impurity found when the air was noted as "fresh,"&c., the impurity not being appreciable to the senses.........	0.196	0.157
Number of analyses in each group......................	75	38

Assuming the average carbonic acid per head to be 0.6 of a cubic foot, these amounts indicate a supply of air as follows:

	Barracks.	Hospitals.
Amount of air supplied per head per hour in cubic feet..	3062	3822

Stated in round numbers, therefore, we may say that while a barrack-room may be kept sweet with 3000 cubic feet, it will take 4000 to keep a hospital ward containing ordinary cases in the same condition. Much more would, of course, be required during times of epidemic or the like.

There is less regularity in the higher orders; but if the whole of the observations, other than No. 1, are taken together, we find a similar indication:

	Barracks.	Hospitals.
Mean amount of carbonic acid per 1000 volumes, as respiratory impurity, in all the observations, when the organic matter was appreciable by the senses	0.601	0.580

Calculating the amount of air supplied as above, we have:

	Barracks.	Hospitals.
Amount of air supplied per head per hour in cubic feet	998	1034

A comparison may also be made by attaching a numerical value to each order, which we may do by making the mean carbonic acid of No. 1 unity, and finding its ratio to the others thus:

No. of Order.	Mean respiratory impurity as CO_2.	Ratio, No. 1 being unity.	Differences.
1	0.1830	1.00	..
2	0.3894	2.13	1.13
3	0.6322	3.46	1.33
4 & 5	0.8533	4.66	1.20

The progression is pretty regular, and the mean difference is 1.22, which differs but little from the individual terms.

Adopting the above numbers as the respective numerical values of each order, we have for *barracks* :

No. of order.	No. of obser-vations.	Value of order.		Total.
2	89	× 2.13	=	189.57
3	88	× 3.46	=	304.48
4 & 5	97	× 4.66	=	452.02
Sums..	274			946.07

giving a mean of 3.45.

For *hospitals*, we have :

2	20	× 2.13	=	42.60
3	46	× 3.46	=	159.16
4 & 5	20	× 4.46	=	93 20
Sums..	86			294.96

giving a mean of 3.43.

Here we find the same numerical value (signifying *close*) applied to 0.580 in hospitals and 0.601 in barracks. There is thus, even in this comparatively limited number of observations, a confirmation of the opinion that more air is necessary to keep an air-space sweet in disease than in health. It is, however, right to point out that in the one case the occupation was continuous, and in the other chiefly at night only.

THE NEW METHOD OF GRAPHICAL STATICS.

APPLICATION OF THE GRAPHIC METHOD TO THE ARCH.

By A. J. DU BOIS, C. E, Ph. D.

Written for Van Nostrand's Engineering Magazine.

One of the most important applications of Graphical Statics in point of ease of solution and saving of labor, is to the arch, both the stone and braced iron arch. We shall consider here only the first or stone arch. The method enables us to find easily and accurately both the thrust at crown and proper dimensions for stability for any form of arch and surcharge, without the aid of tables or the use of formulæ. Indeed, this is the principal advantage of the graphical method, that its solutions are general and independent of particular assumptions. We are in the present case not restricted by any special limitations, but take the arch just as it is in the case considered, and investigate it under the actual conditions to which it is subjected.

LINE OF PRESSURES IN THE ARCH.

We have already indicated (Art. 28, Fig. 16) the manner in which a number of successive forces are resisted by an arch. We see from the force polygon in that figure that the horizontal pressure is the same at every point, and that the vertical pressure is equal to the sum of the weights between the crown and any point. The pressure line is thus an equilibrium polygon formed by laying off the weights, choosing a pole and drawing lines from the pole, etc., as described in our previous articles. If the weights are small and their number great, the equilibrium polygon becomes a *curve.* This curve for equilibrium should never pass outside the limits of the arch. More than this, this curve must under all circumstances *lie within the middle third* of the arch—all its possible positions must be included between two curves parallel to extrados and intrados respectively and distant $\frac{1}{3}$ of the depth from each. The proof of this condition is simple and to be found in any treatise upon the arch. It is unnecessary to give it here, and sufficient to remark that if from any cause the curve of pressure passes beyond these limits the *neutral axis enters the cross section.* That is while on one side of the neutral axis there is compression, on the other side there is tension. But as the mortar is neglected, the joints open freely under the influence of tensile strain, all the material upon the tensile side of the axis is not brought into play at all, and might be removed without affecting the pressure upon the other side. To obtain the entire effective resistance of the

given cross section then, the pressure curve must lie between the above limits.

CONDITIONS FOR STABILITY.

The arch may fail either by rotation about one or several joints, or by the sliding of the joints upon each other. The first is effectually prevented if the pressure curve lies between the limits just prescribed. The second can never take place if the angle between every joint and the direction of the pressure at that joint is well within the *angle of repose.* The curve of pressure being known in any case, it is easy to so dispose the joints that this shall be the case. The whole problem then is simply to determine the pressure curve. The arch is stable if the joints can not slide, and if it is possible in any two joints to take two reactions, such that with the weight of the intervening portion of the arch and its load, the resulting pressure line shall lie so far within the arch that rotation about an edge cannot take place. If the arch is so light and the resistance of the material so slight that only *one* assumption of the reactions can be made, and only one such pressure curve drawn, this is evidently the true pressure curve for stability, and by it the reactions or pressures at every joint are determined.

If, however, the arch is so deep and the resistance of the material so great, that several pressure curves may be drawn, none of which cause rotation about and edge, which of all these curves is the true pressure curve?

We assert: *that is the true pressure curve which approaches nearest the axis, so that the pressure in the most compressed joint edge is a minimum.*

If we assume the material so soft that the pressure line approaches the axis so closely that only one curve is possible, then this is evidently the true curve. If now the material hardens without altering any of its other properties, such as its specific weight or modulus of elasticity, then the position of the pressure curve is not changed. As there is no reason for supposing the pressure line different in an arch built of hard material from that in one originally soft which has afterwards gradually hardened, it follows that the pressure line in all arches of same form and loading has the same position which it would have had if the arch had been originally of the softest material; that is the position which makes the pressure in the most compressed joint edge a minimum.

We have then in any case to ascertain whether it is possible to draw a pressure line, whose sides cut the joint areas within the inner third, for then since we know that there can be a still more favorable position, there is no danger of rotation.*

DIMENSIONS OF THE ARCH—STABILITY OF ABUTMENTS.

The object of the construction of the pressure curve in the arch is to determine also the stability of the abutments. When the live load of the arch can be neglected with respect to its own weight and when the material of the arch presses the usual strength and the pressure line lies within the inner third, then the lower point of rupture lies so low that the rear masonry completely encloses it. There is therefore nothing arbitrary when the form of the arch is given except the *depth.* Since in an arch of less depth than is allowable in practice a pressure line can still be inscribed, the graphical method is unable to determine the proper depth. This must be determined by practice, empirical formulae, and regulated by the strength of the material, etc. We must assume that not only the form of the arch, but also its proper depth as well as its surcharge are given. It is required then to determine the stability of the abutments.

We may regard the abutment simply as a continuation of the arch—so that the arch is continued as such, clear to the foundation; or we may regard it as a wall whose moment about the *joint of rupture* resists the rotation about this joint due to the thrust. Both views are identical, as the entire theory of the pressure curve rests upon the investigation of the rotation. They differ only in the method of expressing the safety of the abutments.

If the arch is continued to the foundation, and the space between it and the road line filled up with masonry, or if the thickness of the abutment increases

* *Colmann-Die graphische Statik.* Zürich, 1866.

from above as the pressure curve requires; or if the abutment consists of partitions and hollow spaces; still in every case the abutment is not to be distinguished from the arch proper—it is stable when the pressure line lies in the interior. If the prolonged is separated entirely from the adjacent masonry, there is no reason for not giving the axis of the prolongation the form of the pressure curve itself. If, on the other hand, there is no separation of the arch and abutment, it is sufficient that the pressure line lie within the inner third, and the abutment is certainly stable.

The supposition that the resistance of the mortar is sufficient to unite the whole abutment as a single block which turns about its under edge, gives dimensions too small. To *insure* safety it is assumed that equilibrium exists with reference to rotation about the lower edge when the thrust of the arch is 1.5 *greater* than the actual. Investigations of French engineers have showed that this coefficient of safety for very light arches is not less than 1.4. The table of *Petit* give 1.9. We assume it therefore at 2.

If therefore the *double* thrust of the arch at the lower point of rupture is united with the weight of the abutment, the resultant should *still* fall within the base. Since it is indifferent in what order the elements of the abutment are resolved, it is best to divide it into vertical slices, and unite the weight of these with the double thrust. The equilibrium polygon thus obtained should cut the foundation base within the edge of the abutment.

When the thickness of the abutment is thus determined, we must construct the actual pressure line by more than the angle of repose. Finally the pressure line itself must lie within the inner third. A single example will illustrate and apply all the above remarks, and will enable the reader to determine readily the dimensions, thrust, joint of rupture, etc., in any case.

CONSTRUCTION OF THE PRESSURE LINE—EXAMPLE.

Thus, in the accompanying Fig. 1, we are supposed to have drawn a given arch to scale. We must first divide the arch into vertical slices and determine the weight of each. If the surcharge has vacant spaces, or is generally of different specific weight from the material of the arch itself, it must first be *reduced.* Thus if the surcharge (spandrel filling, etc.) weighs, for instance, only $\frac{2}{3}$ds as much as an aqual area of masonry in the arch, we must diminish the vertical height by $\frac{1}{3}$. We thus obtain the dotted line given in the figure which forms the *limit* of the reduced laminae, and we can treat the areas bounded by this line, by the vertical lines of division and by the intrados, as homogeneous. We have next to determine the centres of gravity of the various laminae, according to the construction for finding the centre of gravity of a trapezoid (art. 33) and suppose at these points the weights, which are of course proportional to the reduced areas of the several trapezoids, to act. [*All trapezoids must be reduced to equivalent rectangles of common base, the heights of these rectangles are then proportional to their weights, art.* 33.]

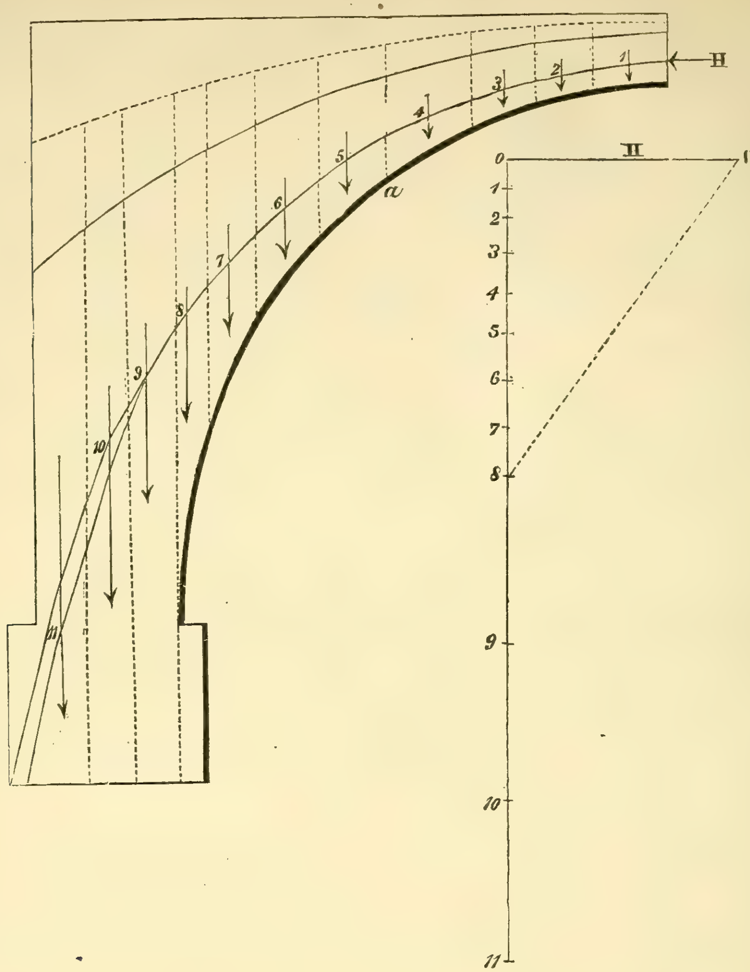
Laying off then these weights in their order we have the force line 0 1 2 3 . . . . . 11, Fig. 2. The weights of the abutment laminae 9 10 and 11, are laid off to same scale as the others, *one half* of their proper length. The reason will soon appear.

1st. *To determine the thrust* H *at crown, and also the joint of rupture.*

We first sketch in a pressure curve by the *eye*, and assume the point of the intrados to which this curve most nearly approaches as the edge of the joint of rupture. Draw now from the corresponding force of the *force line*, a line parallel to the direction of the assumed pressure curve at this point. This line will cut off from the horizontal through the beginning of the force line, our first approximate value for H.

Thus, suppose we have inscribed by eye the pressure curve 1 2 3 4, etc., which gives us the point *a* for the position of the joint of rupture. This point *a* belongs to force 5. Then a line drawn from 5 on the force line parallel to the side 45 of the drawn pressure curve cuts off *o* O in Fig. 2, our first value for H.

Now, assume this value of H as correct, erase the pressure curve by which we have just obtained it, and with this value of H and the forces 1 2 3 4, etc., construct the corresponding equilibrium



polygon. If *this* polygon lies always within the middle third of the arch, it may be taken as the proper pressure line and H as the true thrust. In general, however, this will not be the case. The polygon thus obtained may even pass entirely outside the arch.

We then determine another point of rupture, viz. the point of exit, or the point of the intrados to which the polygon most nearly approaches, and produce the side of the polygon at this point *back* to intersection with H prolonged through the crown. From this point of intersection draw a line which *does* lie within the middle third at the point of rupture, and *then* parallel to this line draw a line in Fig 2 from the end of the proper force, and we thus obtain a second and more accurate value of H. Erase now the preceding polygon, and with the new value of H and the given forces proceed as before, and we shall have in general a pressure line lying everywhere within the middle third. If not, another approximation may easily be made. We thus find by successive approximation, the position of the joint of rupture and the thrust at crown.

2d. *Width of Abutment.*

Since we have laid off the arch weights to scale in their true value, the pressure line thus obtained is the pressure curve for the arch. But we have laid off the abutment laminae 9 10 and 11, *one half* their true value, and the pressure line

thus obtained with the same thrust and and pole O, is the same as if we had taken their true value and *twice* the value of H. Its intersection with the foundation gives us then the proper width of the abutment for stability, according to our assumption of 2 for the coefficient of stability.

3d. *The pressure line being thus known we can easily dispose the joints so as to avoid sliding.*

Thus, by an easy construction, we can determine for any given case of arch and surcharge, the horizontal thrust, the proper width of abutments, and the disposition of the joints. If the dimensions of the arch, as given, are not such as to be stable for the load, it will be found impossible to inscribe as above a pressure line which shall lie within the middle third, and the curve of the extrados or intrados, or both will have to be altered so that this shall be possible.

The pressure line thus obtained does not indeed *exactly* correspond with the true one, as it is still possible to inscribe another which shall deviate less from it. We have also taken the double thrust for the abutment laminae alone, instead of from the joint of rupture. Both deviations render the construction more easy and rapid. It would be found very tedious to take first the *force* polygon (Fig. 2) up to about the estimated joint of rupture, then by long trial find the innermost pressure line, and, finally, after the joint of rupture is by this last line determined, to lay off the remainder of the force polygon and prolong the pressure line through the abutment.

It is far simpler to proceed as above, by assuming the point of application of the horizontal thrust, as also temporarily the joint of rupture. We obtain thus a somewhat smaller value for the width of abutment, but, on the other hand, we have for this reason taken the coefficient of stability at 2, instead of 1.9, as assumed in *Petit's* Tables.

Moreover, the widths of abutment thus obtained are greater than those obtained by the tables, as it is assumed in them that the point of application of the horizontal thrust is at the upper edge of the abutment. Thus, in every respect, the construction gives results reliable and even more accurate than the tables, as we take the arch as it really is, while in the tables suppositions are made with reference to surcharge, etc., which do not hold good for every case.

PROPER THICKNESS OF ARCH AT CROWN.

For this, as has been remarked, we must refer to practical experimental formulæ and the circumstances of the case. The proper depth depends not only upon the rise and span, but also upon the load. The pressure at the extrados at the key, which is in general the most exposed part of joint, should not, according to the best authorities, exceed $\frac{1}{10}$th of the ultimate resisting power of the material. If P is the pressure per unit of surface. H the thrust, and d the depth of keystone joint, then

$$P=\frac{2\,H}{d}$$

since on the assumption that the curve of pressure does not pass beyond the middle third, the maximum pressure is twice the mean pressure $\frac{H}{d}$. This mean pressure then should not exceed $\frac{1}{20}$th the ultimate resisting power of the material. "In the best works of *Rennie* and *Stevenson*, the thickness of key varies from $\frac{1}{30}$ to $\frac{1}{35}$ the span, and from $\frac{1}{26}$ to $\frac{1}{30}$, the radius of the intrados. The augmentation of thickness at the springing line is made by the Stevenson's from 20 to 30 per cent., by the Rennie's at about 100 per cent. *Perronet* gives for the depth at crown the empirical formula $d=0.0694\,r+0.325$ metres, in which r is the greatest length in metres of the radius of curvature of the intrados. For arches with radius exceeding 15 metres this gives too great a thicknes. According to Rankine $d=0.346\sqrt{r}$ for circular arches, and $d=0.412\sqrt{r}$, where r is the radius of curvature of the intrados at the curve."

"The London Bridge is in its plan and workmanship, perhaps, the most perfect work of its kind. The intrados is an ellipse, the span 152 feet, the rise $\frac{1}{4}$ as much, the depth of key $\frac{1}{30}$th the span. The crown settled only two inches upon removal of the centres."—[*Woodbury—Theory of the arch.*]

In general, we must first assume the depth at key in view of the strength of the material, the character of the workmanship, the load, etc. Then the thrust being found as above, we find the mean pressure per unit of area. If this exceeds $\frac{1}{20}$th the ultimate resisting power of the material, we must make a new supposition, increase the thickness, find the thrust and pressure anew, and so on till the results are satisfactory. The ultimate resisting power of Granite may be taken at 6,000 lbs.; Brick, 1,200; Sandstone, 4,000; Limestone, 7,000 lbs. per square foot. These values are, of course, very general, and subject to considerable variations, according to the kind and quality of the material. The strength of the material to be used must for any particular case be determined by actual experiment.

The weight of a cubic foot of stone may be assumed for preliminary investigations at 160 lbs.—brick masonry at 125 lbs.

INCREASE OF THICKNESS DUE TO CHANGE OF FORM.

Having obtained a thickness which satisfies all the conditions, we must, if the arch be very light, make some further provision for the change of form, which is sure to take place after the removal of the centre. By this change of form the pressure line is altered and the thickness must be increased. In general we need only to increase the depth from the key to the springing. This increase need not exceed 50 per cent. at the joint of rupture and weakest intermediate joint.—[*Woodbury—Theory of the Arch.*]

Thus we have all the data necessary for the investigation of any given case, and can determine by a simple and rapid construction the thrust, joint of rupture and proper thickness of the abutments, without the aid of tables or the intricate formulæ usually employed. There is no difficulty in laying down upon paper and verifying all the elements of the most complex case. The method is entirely independent of all particular assumptions, and is therefore especially valuable when irregularities of outline or construction place the arch almost beyond the reach of calculation. It is general, and may be applied with equal ease to loaded and unloaded, full circle, segmental or elliptical arches with any form of surcharge.

MECHANICAL CHANGES IN BESSEMER STEEL.

By ARCHIBALD MACMARTIN, M. E.

Transactions of American Institute of Mining Engineers.

THE Konigin-Marien-Hutte is the only works in Germany where the Bessemer process is carried on by the direct method. The Bessemer plant there, is arranged after the true English type, and the only resemblance to the Swedish mode of procedure is the dispensing with the use of spiegeleisen at the end of the "blow"

In a new department of the establishment, started within three years, each of the converters is turned by means of a very neat and compact reversible engine, the steel shaft of which is an endless screw, which turns against the oblique cogs of a large wheel attached to the shaft of the vessel. An advantage which this arrangement possesses over the ordinary English hydraulic arrangement, is the fact that the endless screw suffices to turn the vessel, in *either direction any number of complete revolutions;* while even the latest American improvements, so clearly explained to us by Mr. Holley at the opening session of this meeting, do not secure even one complete revolution without changing the angle of inclination of the hydraulic piston.

In the endless screw arrangement, there being no limit to the working of the motor in either direction (no return-stroke necessary), the vessel can always, unless outside reasons demand the contrary, be turned around to any desired

position by the shortest cut, whether backwards or forwards. Also, the diameter of the cog-wheel attached to the vessel can be made sufficiently great to avoid all unevenness of motion. In the old department the motive-power still continues to be hydraulic.

If reports be true, the new department produces spiegelized steel, for the manufacture of all-steel rails. But the old department is still, as from the beginning, devoted to the production by the direct method of steel for steel-headed rails. The most remarkable fact connected with this direct steel is the ease with which it welds to the iron of the rail-packets, although no borax or other fluxing agent is used to facilitate the welding. It is very rarely that an exception occurs, and an ingot or a charge is discarded by the rail-mill.

The mixture of pig-iron used for the production of this steel is melted in cupolas of very interesting construction (not to be described here), and consists generally of gray "Konigin-Marien-Hutte," two grades of gray "Georg-Marien-Hutte," of Osnabruck, "Charlotten-Hutte," and "Schmalkaldner-eisen." The last is rich in manganese and resembles spiegeleisen, although its silver-white crystals are, as a rule, much smaller than those of spiegeleisen. It is probably due to a high percentage of manganese in this mixture of iron employed, that it is possible in Zwickau to do what has been tried in vain in England, namely, to dispense with the use of spiegeleisen at the end of the blow.

The five tons of molten iron are blown, till the conductor of the operation is warned by the spectroscope that the charge has come to the condition of steel. Then the vessel is turned over, back downwards, and the blast cut off. In more than ninety cases out of a hundred, nothing further would be necessary. But, to make assurance doubly sure, a mechanical test is applied. No extra time is lost by this; for it is always well to let the finished charge rest in the vessel a short period previous to pouring it into the ladle. This second test is called the "globule-test." Three or four long iron rods are plunged into the metal-bath, at the mouth of the converter, and drawn out very rapidly. The slag adhering contains minute globules of metal, of the same degree of decarburization represented by the whole bath. These, after the rods have been plunged into cold water and the slag thus disentegrated, are collected together and hammered. Those globules which cooled on the outer surface of the slag, are apt to be, in part, superficially oxydized, and are always discarded, because they are almost sure to crack on the edges when hammered. But any wholly bright globule, even slightly irregular in shape, is suitable for the test in question. A number of the chosen globules are hammered upon an anvil with a hand-hammer. If the steel be *too soft* (which almost never occurs), the globule will hammer down very flat and with unbroken edges; but the experienced hand can readily feel that the resistance offered to the hammer is too slight. If the steel be too hard, the globules will crack on the edges when hammered; or their too great resistance to the hammer can just as easily be felt, as can the opposite in the former case.

When the steel possesses the desired degree of hardness, no cracks are seen on the edges of the hammered globules; but yet a perceptible (though not too great) resistance is offered to the hammer But, if any globule that is partially coated with oxyde, or any wholly bright globule larger than 3^{mm} in diameter, hammers out without cracking on the edges, it is a sign that the steel is too soft. There is a limit, then, to the size of the globules taken.

When the steel is shown by the test to have the right hardness, it is allowed to remain as much longer in the converter as may be necessary to cool it, or to get rid of contained gases, etc.; after which it is poured into the ladle and cast into ingots, as in the English method.

When the hammered globules show too great hardness, the blast engine is started again, and the vessel again brought to the upright position, for extra blowing. But, so nearly accurate is the original indication of the spectroscope, that it is rarely necessary, in cases of insufficient previous blowing, to do more than merely turn the vessel up and then immediately down again, in order to make up the deficiency; as will be shown by making a new globule-test.

But, when the very rare case occurs,

that the metal has been blown too far, all that can be done (unless, indeed, it is possible and convenient to finish up in true English style) is to add a small quantity of manganiferous white iron (generally "Schmalkaldner") cold, and then blow a little more, till the spectroscope warns again to stop.

The use of the spectroscope in the Zwickau process is one of the most beautiful expedients in metallurgy, One never tires watching the brilliant changes in the spectrum, blow after blow. The specific causes of these changes have been the subject of much dispute and unsatisfactory investigation. But all are agreed that carbon has something to do with them, whether as such or in gaseous form in such nitrogenous compounds as cyanogen. Whatever be their cause, these changes takes place, and that so regularly that an experienced eye can place full dependence upon them as indicators of the state of preparation of the metal-bath. The spectrum at first appears without lines; but, as soon as the "spark-period" begins to give place to its successor, and the clear flame to extend out of the mouth of the converter, the bright orange-yellow sodium-line quickly makes its appearance, and remains clearly visible till the blast is turned off. After the sodium-line appear the red lines, which represent calcium and lithium; and then a beautiful series of perfectly graded green lines in the green, and pale-blue lines in the blue section of the spectrum, manifest themselves, one after another, each in its series, until, at the climax of the operation, when the greatest heat is attained, the spectrum rivals that of chloride of copper in beauty and brilliancy. A very experienced eye can also sometimes see a beautiful violet line in the violet section at this point.

But the characteristic lines of the Bessemer spectrum are the beautiful band-like, graduated series, in the blue and especially in the green section. In the inverse order to that in which they arose to their climax, these lines gradually diminish in brilliancy, and at last vanish. But some of the green lines still remain after the blue series has entirely vanished; and at this point nothing must be allowed to distract the conductor of the operation from closely watching the spectrum; for the only index (though a perfect one) of the exact end of the operation, is the degree of brilliancy or certain green lines, which remain when the charge has arrived at the point of desired decarburization. For different mixtures of pig-iron, a slight difference in the appearance of the indicating green lines is noticable at this point; and to secure, with the same mixture, a desired slight difference in the grade of steel produced in two different blows, proper allowance must be made, on one or other side of a certain degree of brilliancy of the green lines. This is merely a matter of experience, and any liability to risks, in producing either the same grade of steel with different mixtures of iron, or different grades with the same mixture, is always counteracted by the subsequent globule-test, if only the conductor of the operation be sure, when making either of the above changes, to blow his charge rather too little than too much.

With one pair of five-ton vessels and three cupolas, the ordinary production in Zwickau is twelve to fourteen blows in twenty-four hours.

The ingots, as soon as they shrink enough to be removed from the moulds, are evenly heated in a gas or air-furnace, preparatory to being hammered by a $17\frac{1}{2}$-ton steam hammer, which removes their bevel, and reduces them to a uniform cross-section, a little less than the size of their original smaller end. There is no doubt that, if hammering previous to rolling is advantageous, the tremendous blows of that massive hammer are of great advantage to these ingots. Each bloom is weighed and wheeled to the rail-mill, where, after reheating, it is rolled out into what is called a "platina." One platina corresponds to the steel heads of several rails, and must be cut up into a corresponding number of pieces, of proper length for a rail-packet. The platina is a plate about eight and a half inches wide, and one inch and a half thick, with a longitudinal central-flange on its upper surface of a little more than one square inch cross-section. Each piece of platina constitutes the bottom of a rail-packet (the flange lying uppermost), and granular iron, flat rolled pieces of old steel-headed rails, etc., and piled upon, it,

on each side of its flange; and lastly a fibrous iron platina without a flange, makes a top for the packet and secures a tough bottom for the rail. The packets are brought to a bright welding heat, in ordinary reheating-furnaces, and then rolled, in two heats, into rails, there being twelve passes in the final heat. The welding is perfect, and the fracture of a finished rail shows a head completely of steel resting on two shoulders of granular iron, while a tongue of steel, corresponding to the platina flange, extends from the head one-third of the way down the upright of the rail, penetrating it like a wedge. But the bottom of the rail shows a beautiful fibrous fracture.

The use of crop-ends of steel-headed rails and pieces of broken-up old rails of the same kind, as components of the rail-packets, is worthy of notice. These pieces are first rolled out as flat as the case requires, and two lengths are usually employed in each packet. But, as the steel will not weld to itself, care is taken to lay these pieces so that the head of one piece lies against the fibrous iron bottom of the other, while a layer of granular iron always separates the platina from all parts of these old rail-sections. The crop-ends of the platinas, and those rail crop-ends not long enough for convenient use in the rail-packets, are generally rolled into rail-straps ("laschen"), or, if they are very small, they are used cold, as occasion requires, to cool down the metal, in too hot blows, previous to casting.

This utilization of old rails and crop-ends enables the managers to dispense with the use of a Siemens-furnace for working up their steel-scrap; although this was contemplated, and an agreement made with Mr. Siemens, by which Mr. Jones, of Wales, was sent to Zwickau, to assist in the arrangement and take charge of the starting of a gas-furnace for the manufacture of Siemens-Martin steel. The plan was, for the time, given up, and Mr. Jones (who has since, with me, constructed and is now running a Siemens-furnace, with the latest improvements, near Providence, R. I.) was, while the matter was in abeyance, given charge of the furnaces where the steel ingots are heated for the hammer. I was at that time (1871), through the kindness of Herr von Lilienstern, the general superintendent, allowed the free run of the works as a "volunteer;" and thus Mr. Jones and I were enabled to try experiments with the steel, aided by such useful auxiliaries as some very hot-air furnaces and a 17½-ton steam-hammer.

The experiments to be here recorded had to do with an investigation into the effects of heat upon hammered steel.

We found that the thoroughness of the hammering had nothing to do with the coarseness or fineness of the grain of steel, provided the hammered piece were subsequently exposed, for any protracted period, to a very high heat. I was, at the time, preparing a Zwickau collection for the metallurgical cabinet of the New York School of Mines, and it occurred to me to illustrate this property of steel by a series of samples. We took a small test-ingot, and, after heating it as high as the ingots are usually heated for hammering, hammered it out from its original size of 3 inches square into a bar about 1¼ inches square. The grain was then very fine throughout, just as in the ordinary hammered samples taken from every blow. The bar was then put into the furnace again and left from two to three hours exposed to a heat not quite as high as that at which the steel-headed rail-packets are rolled. It was then taken out of the furnace, and, as its outside now shows, was hammered for only one-half of its length and then bent up into a horseshoe-shape, so that its two ends could be viewed side by side. There were only four blows of the hammer given to it—one on each side; and yet, when enough of each end was broken off to show the interior structure of the two halves, a most astounding contrast presented itself. The end not hammered since reheating had a much coarser and much more distinctly crystalline structure than even the coarsest of large unhammered Bessemer ingots, while the rehammered end was just as fine in grain as the whole hammered bar had been before reheating. The fracture of the unrehammered part resembled, indeed, more than anything else, that of galena of the same degree of coarseness. This specimen, with its two contiguous fractured-ends, can be seen at any time in the metallurgical cabinet of the

School of Mines, together with samples of hammered and unhammered ingots (with which to compare it, as to grain), a section of platina, and one piece of a steel-headed rail, from Zwickau, beautifully showing by fracture the interior structure, with the wedge-like penetration of the steel-head into the iron body of the rail, and the exceedingly fibrous quality of the rail-bottom. The practical bearing of the facts proved by these samples is of more importance than may at first appear.

If we apply them to the rail manufacture at Zwickau, the question immediately arises: "Of what real benefit is the use of a steam-hammer there for blooming the steel ingots?" As everybody knows, they could be brought down to shape at much less expense by a pair of rolls, as in many other works in this country and abroad. But assuming that, of a hammered and a rolled bloom, drawn down to the same size and shape from two similar steel ingots, the former has a much more compact structure than the other, it does not by any means surely follow that the same or an analogous difference will exist, after the two blooms have been similarly heated, till they are soft enough to roll out into platinas.

But, even if experiment should prove such a difference, can it be supposed that its effects would be in any measure apparent in the final steel-headed rails made from these two different platinas? It seems to me that each of the two platinas would, just before the rolling of the rail-packet, have the same coarse structure that we see in the unrehammered section of our horseshoe-shaped sample, however great the difference in grain may have been previous to their exposure to the welding-heat. This can fairly be assumed from the fact that the specimen referred to was not exposed to a greater than a welding heat.

The application of this subject to the manufacture of all-steel rails can be satisfactorily determined only by still further experiment; because the temperature at which these are rolled is less then a welding-heat, and also the thickness of the blooms, when they last leave the reheating-furnace, is much greater than that of the platinas at Zwickau, and this would probably partly counteract the crystallizing effect of the heat. Such further experimentation would do much to throw light upon the discussion so ably carried on before the Institute, about a year ago, by Messrs. Holley and Pearse, upon this same subject of "Hammer or No Hammer?" These gentlemen have it in their power to seek, in a comparatively untried field, for a ratifying test of the correctness of their theories on this subject, and it is sincerely to be hoped that such a course will be pursued.

THE CONSUMPTION OF IRON PER CAPITA.

From the Bulletin Iron and Steel Association.

By the phrase, "consumption of iron," is meant the utilization of iron in its raw or unworked state, as pig iron, blooms made direct from the ore, castings direct from the blast furnace, and scrap iron. We include scrap iron (by which phrase we mean all old iron) because whenever used it displaces at least its own weight of pig iron or blooms. If it were not used, these would be. Correctly speaking, iron is never *consumed*. Its quantity may be slightly diminished by wear and tear and by the action of the elements, but it is never wholly lost. It can not be eaten like bread, nor burned like wood. In consuming or utilizing iron, therefore, after its conversion from the ore, we merely change its form. In an inquiry into the consumption of iron by a nation, the object should be to ascertain how much *pig iron or its equivalent* is required to meet the industrial wants of that nation. If we aim to ascertain the annual consumption of iron by that nation, evidently the quantity of iron actually consumed in any year can not be decreased upon the pretext that a portion of it had been used ten or twenty years before and cast aside after it ceased to be of service. The accept-

ance of this proposition would not lead to correct results.

In the able and exhaustive report on The Production of Iron and Steel, by the Hon. Abram S. Hewitt, United States Commissioner to the Paris Universal Exposition of 1867, there occurs the following estimate of the consumption of iron per capita in all countries at that time :

" Allowing for the production in barbarous countries, and something for the use of scrap iron, it may be stated in round numbers that the production, and consequently the consumption of the world, has reached 9,500,000 tons of 2,240 pounds each, or 21,280 millions of pounds ; so that if the population of the world has reached 1,000 millions the consumption is a little over 20 pounds of iron per head. A careful calculation, after allowing for the iron exported, shows that the consumption per head in England is 189 pounds of iron. The consumption in Belgium has reached about the same limits. The consumption in France is 69½ pounds per head, and in the United States not far from 100 pounds per head. If the industry of the whole world were as thoroughly developed as in Great Britain, the consumption of iron would reach nearly 90,000,000 tons per annum. If brought to the standard of the United States, a little less than 50,000,000 tons per annum would answer ; or if to that of France, a little over 30,000,000 tons would be required ; figures to be increased further by the steady increase of population in the world."

Since this estimate was made, statistics show that the world's annual production of iron has increased from 9,500,000 gross tons in 1867 (Mr. Hewitt's figures) to 15,000,000 tons in 1874. The increase of the population of the globe has certainly not kept pace with this increase in production ; consequently the consumption per capita has increased. It was probably over 30 pounds in 1874, against 21 pounds in 1867, as estimated by Mr. Hewitt. Making no allowance for the use of scrap iron, an estimated population of 1,100 millions in 1874 will give in the total product of cast or pig iron in that year exactly $30\frac{6}{11}$ pounds consumption per capita. This increased consumption is easily explained by the increased demand during the past few years for iron for railways, iron ships, iron bridges, iron buildings, iron pipe, and other comparatively new uses of iron. This stimulus to the consumption of iron has, however, been sensibly weakened in most countries since the autumn of 1873, when the American panic occurred, and it is not at all an open question whether the world's consumption of iron will increase in the same proportion during the decade which began with 1874 as during the decade which then ended. It will not. The depressing effects of the financial revulsion which has affected many countries besides our own will restrict this consumption for some time to come, particularly in the interruption to the building of railways. The extensive substitution of steel rails for less durable iron rails, and the strong tendency to substitute steel for iron in many other forms, will necessarily lessen the demand for pig iron. The increased attention now given to the reworking of scrap iron, especially in this country, while not in a strict sense affecting the consumption of iron, will also reduce the demand for pig iron. Finally, the occurrence of great wars is one of the most powerful influences in stimulating the use of iron, and it is scarcely possible that Europe and America can be convulsed during the decade upon which we have just entered by such violent and destructive struggles as the past few years have witnessed.

The consumption of iron per capita in the United States is placed by Mr. Hewitt at 100 pounds in 1867. Without inquiring into the basis of Mr. Hewitt's calculation, we proceed to inquire whether the per capita consumption of iron by this country has since advanced beyond his estimate, and if so, how much. We will first take the census year 1870, for which more detailed and reliable data exist than for any subsequent year. From the census report and the statistics of the Treasury Department we have compiled the following table, showing the quantity of pig iron or its equivalent which was actually used in the census year :

	Net tons.
Production of pig iron in the census year 1869–70....	2,052,821
Consumption of domestic and imported scrap iron, in the census	

year, in the manufacture of 1,350,663 tons of rolled iron, 1,115,000 tons of castings, 103,288 tons of forgings, 110,808 tons of blooms, and 30,354 tons of steel..	630,442
Importation of pig iron in the fiscal year 1869–70, corresponding very closely to the census year.......	171,677
Importation of 419,924 net tons of rails, bar iron, castings, and forgings, in the fiscal year 1869–70, in approximate tons of pig iron..	493,685
Total quantity of iron made in the United States and imported in the census year 1869–70.............	3,348,625
Deduct 1,557 tons of pig iron exported from the United States in the fiscal year 1869–70, and 5,500 tons of pig iron worked into finished iron, exported in same year	7,057
Quantity of iron actually used in the United States in the census year 1869–70, the quantity held in stock at the close of the year being estimated as equal to that carried over from the preceding year....	3,341,568

The 3,341,568 net tons of iron contained 6,683,136,000 pounds, which, if divided by 38,925,598, the total population of the United States in the census year, give 171 pounds as the per capita consumption in that year. This result is so much more gratifying to our national pride than that reached by Mr. Hewitt only four years before the taking of our last census, that we were ourselves astonished by it, and we therefore give in entire frankness in the above table the process by which it was reached.

The year 1872 was probably the year of greatest activity in the consumption of iron in this country. It was the year of the iron famine, when production and consumption were both stimulated to the utmost. In the following statement we have endeavored to ascertain the quantity of raw and scrap iron used in that year. The elements of the calculation are the same as those which were employed in ascertaining the consumption in the census year, but some of the data are necessarily estimated. In the certain data we have the production for the year of pig iron, blooms, and steel, and the imports and exports of iron of all kinds; while in the estimated data we have the stocks of pig iron on hand at the beginning and end of the year, the quantity of cast iron produced by the foundries, the quantiy of scrap iron used, and the production of rolled and forged iron except rails. The quantity of cast iron and other estimated iron products is obtained by assuming that the output of the foundries, bar mills, etc., had increased from 1870 to 1872 in the same proportion as that of the rail mills, which is definitely known. To ascertain the quantity of scrap iron consumed in obtaining all these products, including rails, we have assumed that in 1872 the proportion of scrap to each of these products was the same as in 1870. According to the census returns, one-third of all the iron forged and rolled in the census year, one-eighth of the pig and scrap blooms, one-eighth of the castings, and one-fourth of the cast steel were made of scrap iron. With these explanations we submit the statement of aggregate consumption in 1872:

		Net tons.
Production of pig iron in 1872. ...		2,854,558
Consumption of domestic and imported scrap iron in the manufacture of 1,941,922 tons of rolled and forged iron, 28,000 tons of pig and scrap blooms, 1,800,000 tons of castings, and 35,000 ton of cast steel in 1872..................		884,581
Production of blooms from ore in 1872..............................		30,000
Importation of pig iron in 1872....		295,967
Importation of 643,639 tons of rails and other rolled iron, 5,875 tons of forging, and 407 tons of castings in 1872, in approximate tons of pig iron...		764,197
Total pig and scrap iron made and imported in 1872...............		4,829,303
Deduct 1,477 tons of pig iron, and 5,203 tons of pig iron worked into finished iron, exported in 1872	6,680	
Deduct the estimated excess of production of pig iron over consumption in 1872	300,000	306,680
Total consumption of pig and scrap iron and blooms by the United States in 1872..................		4,522,623

The above 4,522,623 net tons of iron contained 9,045,246,000 pounds. The population of the United States in 1872 we estimate at 40,500,000. These figures give us 223 pounds as the per capita consumption of iron in the United States in 1872. The increase in our consumption of iron per capita from 1870 to 1872 was the difference between 171 and 223 pounds, namely, 52 pounds, or over 30 per cent. This increase in two years is

marvelous, but it must be remembered that 1871 and 1872 were themselves marvelous years. If our premises in the two calculations we have made be accepted, no other results than those reached are possible.

The consumption of iron per capita in the United Kingdom of Great Britain and Ireland is stated by Mr. Hewitt to have been 189 pounds in 1867. It has since increased. Without making any allowance for the large consumption of scrap iron in that country, which has never been definitely ascertained, and which it is impossible accurately to estimate, we obtain from the production of pig iron alone, as will be seen by the following itemized statement, a larger per capita consumption in 1872 than in 1867.

	Gross tons.
Production of pig iron in 1872.....	6,741,929
Deduct 1,332,726 gross tons of pig iron, 296,575 tons of castings, and 1,974,236 tons of rolled and forged iron and steel, exported to other countries, in approximate tons of pig iron..................	3,603,537
Left for home consumption........	3,138,392

These 3,138,393 gross tons of pig iron give us 7,029,998,080 pounds, which, divided by 31,817,108, the population of the United Kingdom in 1871, show a product of 220 pounds as the per capita consumption of iron in 1872. We have not taken into consideration the inconsiderable imports of iron in that year, which would add very slightly to the consumption. The scrap iron consumed would largely increase it.

The figures given and the facts which we have made no attempt to reduce to figures point to a much larger per capita consumption of iron in Great Britain in 1872 than in this country. But we are not prepared to accept this conclusion. A very large portion of the iron retained in Great Britain for home consumption is converted into iron ships, machinery, hardware, cutlery, etc., for sale to other countries. These iron and steel products should properly not be confounded with like products which are permanently retained in the country. In the United States, however, so comparatively small are our exports of machinery, etc., and so nearly are they balanced by our imports of similar commodities, that it is fair to assume that all of the iron nominally retained here is actually consumed by our own people.

We shall never know the exact facts of per capita consumption of iron in any country. The foregoing calculations and deductions are submitted as the result of a careful inquiry into the *probable* consumption by the world, the United States and Great Britain.

WATER SUPPLY AND DRAINAGE.*

By W. A. CORFIELD, Esq., M.A., M.D.

III.

SEWERS AND SEWERAGE SYSTEMS.

The water is brought into the town to be soiled, and it must be removed ; and besides this dirty water which has to be removed, there is the surface water, and the subsoil water that have to be removed also ; together with a quantity of refuse of all sorts, with various impurities from manufactories, from slaughter-houses, from animal sheds, together with slops from private houses, and so on. This impure water is carried away from towns by means of pipes, known as sewers, and I want at once to explain to you in a few words, the difference that is to be kept in sight between a sewer and a drain. A sewer is a pipe for removing impure water, water that has been fouled ; a drain, as Mr. Bailey Denton said in a letter to the *Times*, is meant to take the wetness out of soil ; it is meant to dry the soil—it is not meant to carry away impure water.

As these sewers are to carry away impure water, it is perfectly plain they must be impervious to water, or they may, on certain occasions, let it leak

* Abstract of lectures delivered before the School of Military Engineering at Chatham.

out into the subsoil of the town underneath the houses, and also into the wells, if there are any. If they are impervious, the water of the soil, the subsoil water at any rate, won't get into them and so they will not act as drains. Now you will see directly why it is necessary to drain the subsoil underneath the streets and houses. That it is necessary I can show you in a half a minute.

It has been perfectly clearly shown by Dr. Buchanan, from statistics of the death-rate of certain towns that have been sewered, that in those towns which have had sewers so constructed that the subsoil water of the town has been lowered, the death-rate from consumption has increased in a most extraordinary manner. In the case of certain towns the death-rate from consumption has been reduced by half the total number of deaths, by 50 per cent, by the lowering of the subsoil water consequent upon sewering the town as it is called. But these sewers were so constructed that they acted as drains as well. Towns which have been sewered with impervious pipes throughout, so that no reduction of the subsoil water had been effected have shown no decrease in the death rate from consumption, and some have shown an increase. So that shows you that it is necessary to drain the subsoil.

Then from the incompatibility of having pipes which both drain the subsoil and are impervious, so as not to allow of the sewage to escape from them, it has been suggested to have two systems—to have drains and sewers. Mr. Menzies has been the great advocate of having what is called the separate system. His plan was to have deep sewers, pipe sewers which are impervious, and then rather superficial drains to carry off the flood waters. This plan would not provide for actually draining the subsoil unless some special provision were made for it. The usual plan that is practised is to build sewers large enough to contain all the drainage water and any reasonable amount of storm water that may fall upon the land which is sewered, but it is perfectly ridiculous to use them for intercepting natural watercourses, as is done in so many cases.

Some sewers in the South of London actually collect water from natural watercourses which ought to be allowed to run straight into the Thames. The argument for admitting this extra amount of water into sewers is that they will be kept cleaner, and that they will flush themselves naturally, as it were. But against this is to be placed the difficulty of dealing with the increased amount of water at the outfall. I may speak to you of that, however, bye and bye.

Now for laying main sewers you must have accurate plans of the places, with the levels of the surface along the roads and the streets, and the levels of the deepest cellars, so that the sewer of the street may always be below the level of the lowest cellars. You must also know the levels of high and low tides, if near to the sea. The general plan, according to Mr. Rawlinson, ought to be made on a scale of two feet to a mile, and the detailed plan on one of ten feet to a mile.

I am now going to refer you to an important discussion that took place before the Institution of Civil Engineers in 1862 and 1863. You will find it in Vol. 22 of the *Proceedings of the Institution of Civil Engineers.* I shall have to refer to this discussion several times. The first point to be attended to in laying out main sewers is that they shall be straight from point to point. There is no reason that they should follow exactly the middle of the streets where they are not straight, but they should be made straight from one point to the next. The curves should be gentle, not greater than 22½ degrees, for instance. The junctions should be, as in the case of the main water pipes, curved. Rankine tells us that main sewers should not be less than two feet broad, and that the velocity in them should not be less than one foot in a second, for fear of choking up, nor greater than four feet and a half in a second, because with a greater velocity than this you have too much scouring. The usual plan, then, is to make these drain sewers, as I call them, sewers which are capable to a certain extent of acting as drains also. That end is often realized by setting the bricks of the invert, as it is termed, in cement, and setting the others with mortar. The bricks of sewers ought always to be set in hydraulic mortar or in cement. These drain sewers, I should

tell you, are on the plan of the oldest sewer we know of, namely the Cloaca Maxima in Rome. That Cloaca Maxima was not constructed as a sewer: it was originally a drain. A great deal of blame has been thrown upon the Romans because the Cloaca Maxima was not made impervious; but we must remember it was originally constructed as a drain. It was formed to drain off the water about the Forum, and it did so, and does so to this day. It only came afterwards to be used as a sewer, that is to say, to have refuse matter thrown into it, and that is no doubt how we have got our system of drain sewers, and there is no doubt that the sewers in many towns in England were originally built as drains.

The first thing to mention is the trench. Mr. Rawlinson tells us, in a paper that I have already quoted to you, and which is entitled "Suggestions as to plans for main sewerage and drainage," that the most difficult earth to deal with is quicksand, and as a rule it should only be opened in short lengths. The trench may require to be close timbered; and in all cases the greatest care should be exercised in taking the timbers from the sides of the trenches so that none of the side earth may fall down upon the sewers.

With regard to the depth of the trenches, of course this must vary very much in different places. The only condition is that they require to be placed deep enough to drain all the cellars. I may mention, as an example, that at Stratford-on-Avon the sewers are constructed from 16 feet deep down to 4 or 5 feet in many other parts. At Rugby they average 11 feet in depth, but they vary from 7 to 25 feet. One of those papers that I quoted to you from the *Proceedings of the Institution of Civil Engineers* (Vol. xxii., p. 265), says, that the average depth is 12 feet, but that the depths vary much. Tunneling may be required, as practised now in the large outfall sewer being constructed at Brighton. Tunneling, however, should never be resorted to when it can be helped, because much better supervision can be exercised over the construction of a sewer when you have a trench than if you have a tunnel. This is perfectly clear, and also for the same reason, night work should not be encouraged: the men should work in the day time.

Now as to the incline. The incline, we are generally told, should not be less than 1 in 600. Sometimes, of course, that cannot be got. The incline must vary very much with the natural incline of the soil. If possible, you should have it about 1 in 600 in mains, and a greater incline in the smaller sewers, and the greatest incline in the house sewers. The incline of the pipe-sewers that come from the houses should not be less than 1 in 60. Where sewers are joined the incline should be greater. Where a small sewer enters into a large one there should be a quicker incline for some little distance.

Another point is this—that a larger sewer should never open into a smaller one; neither should a sewer open into one of the same size, but always a smaller one into a larger one. The inverts should not be level. The invert of a smaller one should be higher up than that of the larger one, so that there may be a fall. "Main sewers and drains should be adapted," as Mr. Rawlinson says, "to the town area, length of streets, number of houses, surface area of house yards and roofs, number of street gullies, and volume of water supply."

With regard to the size and shape of the main sewers. The size is, of course, very variable indeed. I told you that Professor Rankine said they should not be less than 2 feet broad. They are often made less than two feet broad. Perhaps the best thing is to give you an example. It is taken from a discussion in the volume of the *Proceedings of the Institution of Civil Engineers*, which I referred to a few moments back. Mr. Newton said that "In purely urban districts a rainfall of one inch in half an hour ought to be provided for; thus, on the 29th July, 1857, he registered at Preston three quarters of an inch of rain in 35 minutes, and on the 8th October, 1861, nearly the same depth in 30 minutes. On the latter occasion an egg-shaped brick sewer, 4 feet 9 inches high by 3 feet 2 inches wide, and 300 yards in length, with a fall of 1 in 156, carried away this water from a closely built and densely populated district containing 117 acres. In another part of the town, which was also built upon, and which

contained 85 acres, a sewer 3 feet 6 inches high by 2 feet 4 inches wide, with a fall of 1 in 75, carried off these storms without causing any damage, and without the water rising in the cellars, which were generally from 1 foot to 2 feet below the soffit of the arches. In both cases, however, the sewers were under pressure, and on the first occasion the water rose 18 inches, and in the other case 1 foot, in the man-hole shafts." (Vol. xxii., p. 295.)

"The London main sewers vary from 4 feet in diameter, to 9 feet 6 inches by 12 feet in some cases. The three northern outfall sewers are each 9 feet by 9 feet with vertical sides, the southern outfall sewer 11 feet 6 inches in diameter." It is a good plan to make what are called intercepting sewers if there are considerably different levels in the town, or if the sewage has to be pumped at the outfall. This you know is done with the sewage of London on both sides of the river. There are two intercepting sewers in the south of London, and the sewage runs by gravitation, in the high level sewer, right away to the outfall at Crossness, and by the southern sewer, it runs also by gravitation, as far as Greenwich, where it is all pumped up into the outfall sewer, and then runs away to Crossness, where it is all pumped up into the Thames.

On the north side of London, there are three, and the sewage of the two lower ones is pumped up into the highest at Abbey Mills, and thence flows on to the outfall at Barking Creek.

Now for the shape. The best shape has been decided to be the egg shaped section. There are plenty of shapes in use. The rectangular section is evidently bad. The amount of friction is very great and likewise such sewers become choked up with deposit. A flat top has been used, but it is obviously bad. It is not so strong; and even the Romans, as in the Cloaca Maxima, used an arch. The best shape is an oval section with the smaller end downwards. Another advantage of this is that there is a saving of a material. Sewers less than 2 feet in diameter are better made circular. There was, for a long time, a dispute as to the different advantages of brick and pipe sewers. You will find in the 12th Vol. of the *Proceedings of the Institution of Civil Engineers* a paper, a very important paper, by Mr. Rawlinson, in which he supported very strongly the use of pipes. You will find that there was a great deal of dispute as to their efficacy. Mr. Rawlinson laid down three propositions that he thought should be borne in mind in laying out the sewerage of a town. In the first place, the sewers cannot receive the excessive flood water even of the urban portion of the site. That is perfectly true; they have in certain places been made large enough to do that. In the second place, according to Mr. Rawlinson, they ought not to be combined with the natural watercourses which drain large areas of the suburban land previous to entering the urban portion. No doubt sewers are frequently combined with watercourses which ought to go directly into the rivers. In the third place, they should be adapted exclusively to carry the liquid and solid refuse from the houses in such a manner as to cause the least possible nuisance to the inhabitants. These conclusions were then very much disputed, as also was the conclusion that sewers should be as small as possible and impervious.—The opponents, no doubt, who disputed these statements, did so from the fact that they did not sufficiently appreciate the antagonism that exists between sewers and drains. Mr. Robert Stephenson, on that occasion, expressed his "conviction that for certain localities. if pipe-drains were sufficiently strong to resist fracture, and sufficiently large to avoid being choked up, they might be advantageously employed to form the connections of houses, courts, and other small localities, with the main sewers, which should be constructed of brick, of such dimensions as to admit of easy internal inspection and repair, and be of form (except where the flow of water was at all times considerable) that the radius of the curved bottom should be able to gather a small supply of water into a sectional area affording the same hydraulic mean depth as in a pipe-drain of a diameter merely adapted to discharge the minimum flow." So that after all this discussion the result which was come to was this: that impervious pipes—glazed earthenware pipes—were, on the whole, the best for house drains, small streets, courts and places of that sort,

but that they were not advantageously to be used over 12, 15, or at the most 18 inches in diameter. Certainly, when above 18 inches in diameter, it is cheaper to make a brick sewer of oval section than to lay pipes.

In very wet soil, Mr. Rawlinson has used iron inverts to prevent the subsoil water coming into the sewer and keeping it continually full up to a certain height. Mr. Simpson has described iron pipes to be used for sewers where there are bad foundations, as in running sand ; there is a plan for preventing subsoil water from getting into sewers without using cast-iron pipes, which is described by Messrs, Reid and Goddison, of Liverpool, in the British Association Report for 1870. They have introduced a subsoil drain and pipe rest to be placed beneath the pipes. It has got a section like the letter D.  The pipe sewer is laid upon it, and it acts as a drain to keep the subsoil water below the sewer.

With regard to the outfalls—the outfalls ought, if possible, to be quite free. The first thing that you have to do is to choose the best place for the outfall. For that there are no general rules whatever, and you must be guided entirely by the nature of the locality. Most sewers having been originally constructed as drains, it is perfectly plain that their only outfall is into the sea or into a river, and so most of the outfalls are built into the sea or into rivers, and the sewage is thrown away. We shall in the next lectures consider some other methods of dealing with sewage.

If possible the outlet should be free. If it cannot be free there must be some means adopted for preventing the sewage getting backed up in the sewers, especially when the rivers are high, or at high tide in the sea. If the sewage is allowed to get back in the sewers you may get the cellars flooded, and you will certainly get sewer air forced up into the town. One way of preventing this is by causing the outfall to open into a large tank out of which the sewage is continually pumped. Another plan is simply to have a flap to the mouth of the sewer—a flap which shuts and keeps it full of sewage. In that case the outfall has to be made large enough to contain an enormous quantity of sewage. Then it should certainly not be taken—that is if you drain into a river—into a river near the town, and certainly not above one. The better method is perhaps to have a large tank, if the outfall sewer must be below the surface of the water. Where you have rivers with considerable difference in the level, a plan has been adopted for discharging the sewage in summer when the river is very low by means of a subsidiary pipe. This cast-iron pipe is taken at a lower level into the river. There is a valve capable of being raised by a windlass, which valve prevents the sewage coming out by the main outfall. The ordinary sewage of the town can then run away by this cast-iron pipe, and get off into the river at a lower level. This plan has been put into operation at Windsor by Mr. Rawlinson; so that the ordinary amount of sewage need not run out by the main outfall high up when the river is low, in which case it would run down the banks causing a nuisance. When there is an enormous amount of sewage and a flood in the river, and of course the river is high, then it is allowed to come out by the main outfall. When there are steep gradients in sewers there ought to be steps made, and flaps placed at the upper parts, and at such places also there ought to be ventilators. Ventilators are best constructed to open at the level of the street, and are best made in connection with man-holes. In the first place I ought to tell you that it is absolutely necessary to ventilate sewers. It is perfectly certain that a certain amount of sewer air, as it is called, is contained in all sewers, and is given out from sewers, and is given out from sewage whether there is much stagnation or not. Where there is great stagnation the more is evolved. The strongest argument for ventilating sewers is the argument used by those who say they should not be ventilated. They say they should not be ventilated because they can be securely trapped, and the small amount of gas that does accumulate in them can be prevented from coming into the houses. Now this fact that sewers need to be trapped is the best argument to show that it is neccessary to ventilate them. I should tell you that all water traps are, essentially, bends in pipes which will hold water. Water traps

are of very little use against sewer air. I do not mean to say that the air will often actually force them, though it will do that sometimes ; but what I mean is that most of the dangerous elements which are the constituents of sewer air are soluble in water and are evaporated and given out, so that it is very little use to rely on water traps, especially if they are placed under pressure. Therefore ventilation must be provided.

Now this ventilation has been carried out in very various ways. The simplest way, of course, is to allow a certain number of the openings into the sewers in the streets to be untrapped, and then the sewer air escapes into the streets.

That was the plan condemned some years ago, because it allowed the sewer air to come out straight into the streets, and to become disagreeable to persons walking. That plan, however, is certainly very much better than letting it remain in the sewers, from which it will get into the houses, as it is certain to do, through weak points.

Another plan was to have special ventilating pipes carried up to the top of high buildings. These are very well in their way, but they are certainly not sufficient. Sometimes at the top of these pipes, Archimedean screws have been placed. At Liverpool an enormous quantity of these Archimedean screws have been placed at the top of such pipes, and more are now being placed. But I must tell you with regard to these that Drs. Parkes and Burdon Sanderson, in their Report lately on the Sanitary Condition of Liverpool, made experiments, and found that these Archimedean screws altered the pressure of the air in the sewers to a very trifling extent, so that they did not seem to be of any great value.

Another plan is to connect the rainwater pipes with the sewers directly, or at least some of them, and to leave them untrapped. If you do this, it is necessary that rain water pipes should be thoroughly well constructed and well jointed, or else air will escape into the neighborhood of the houses. But the best plan of all is to have plenty of openings into the main sewer directly over it, and to have special ventilating openings connected with the man holes along each sewer at certain intervals, in the middle of the streets. You must have man holes, and where a sewer makes a bend there ought to be a man hole ; and there likewise there ought to be a ventilating shaft, and also at every one of the steps which I formerly mentioned to you. Where you have a steep incline you should have a step and a fall, and there, there ought to be a flap and a ventilation shaft provided with charcoal trays.

There are two or three ways of doing this, one is to have a ventilating shaft at the side of the man hole. The air that comes up the man hole passes into the ventilating shaft and through the charcoal and out into the street, and the air is deodorized by passing through the charcoal. That is one way. The dust and dirt which will collect at the bottom of the shaft can be easily removed through the man hole. Another plan is to suspend charcoal trays at intervals in the man hole itself, and then to have an opening through which the deodorized gas goes. If you have plenty of these openings along the sewers into the streets there will not be much nuisance. Then besides ventilation, sewers generally require flushing, or at any rate cleaning out. A deposit occurs in certain parts. Now the old plan used to be to make all main sewers so that a man could go through them. That plan is not now employed, because flushing has been adopted instead of cleansing out by hand labor, that is to say to a very considerable extent. Flushing is performed either by stopping the sewage at certain places and so giving it a higher head, which is the plan often adopted, or by having some special reservoirs of water (collected for the purpose) at the higher parts of the sewers which can be allowed to rush down them ; or again, by making arrangements with the water companies for the supply of a sufficient amount of water to flush them continually. And they should be flushed regularly, or deposit is sure to occur. The Paris plan of flushing the sewers is interesting. You know they have in Paris enormous subways under the streets, and the sewer runs along at the bottom of the subway. This subway has a rail on each side of it, and they flush the sewer in this way : a wagon is run along these rails, and there is a flap which descends

from the wagon into the sewage below. The force of the sewage pushes this flap on, and carries the wagon on too, and the flap of course displaces everything before it. A certain amount of space is left beside the flap, so that the sewage rushes past this, and it in fact chases everything before it that stands in its way, so far as deposit is concerned. Of course the expense of flushing sewers with water is very much less than that of cleansing them by hand labor. I could give you some instances of the amounts of the cost in each instance, but I do not know that it is necessary.

We have now followed the course of water from the place where it is collected into the town, and we have also described sewers. I began by describing to you the outfalls, because that is the natural way of proceeding, not because the water followed that course, but because, before you have small drains and sewers in a town, you want the outfall and the main sewers.

I have now before I go any further a few more points to tell you with regard to the house sewers, or house drains, as they are generally called. In the first place, I have already told you that the fall of the house drains should not be less than 1 in 60. Then, the next point is that house drains ought not to run underneath the basements of houses. They generally do so, as you know perfectly well. If they do they ought to be made of impervious pipes laid in concrete. The next point is that they ought invariably to be ventilated. If the water closet system is used perhaps the best way of ventilating them is to allow the pipe which comes from the closets—the soil pipe—provided it descends outside the house, as it always should, to be untrapped at the bottom, and to be open at the top, so that the air from the house sewer finds exit into the open air continually. If the water closet plan is not adopted there ought to be one or more special pipes for ventilating the drain carried up to the highest point. Or, again, some of the rain water pipes can be left untrapped; but this is not so good a plan. If the soil pipe be inside the house it should be trapped at the bottom and ventilated at the top, and then a special ventilating pipe must be provided for the sewer. Another plan, an excellent one, in addition to this, if the house drain be long enough, is to cut it off—to make a break in it, as it were—before entering the main sewer, and that is done by making it discharge into a ventilating shaft. There is a swing flap on the end of the house drain in the shaft, which is shut except when the water is running. The air which comes up from the street sewer into the shaft cannot pass up the house drain, but ascends through trays of charcoal, and finds its way out into the open air through openings which are left between the bricks at the top of the shaft. The whole thing is covered with a stone slab, just above the level of the ground. If you want additional security you can place a syphon between the ventilating shaft and the street sewer.

Now if a trap is placed in the cellars, or basement of a house communicating with the drain, a precaution has to be taken, if there is any chance of the sewage backing up. In that case a trap has to be placed which will prevent sewage from flooding the basement. This is done by means of a heavy flap trap.

The common traps used for yards, and even for back kitchens, and so on, are what are called bell traps. They are about the worst kind of things that could be devised, and that is why I mention them. The bell trap merely consists of a sort of inverted tumbler placed over the head of the pipe that leads into the drain. The rim of this tumbler dips into a groove, which is supposed to be filled with water. The water that passes through the perforated top which is fixed on to the tumbler can find its way round the edges of this bell, as it is called, and so into the drain. The danger is this, that the instant this top is taken off it takes the bell off as well, and then sewer air can get up into the house or yard. Now these things are continually being taken off, or left off, and therefore that kind of trap should never be used. The best to put instead of it is an earthenware syphon trap. The advantage of this is, that if the top is taken off, as it continually is, to sweep the yard or basement, it does not matter at all, bacause the top has nothing to do with the trap itself. With this syphon, if you want to ventilate the drain at that particular point, you can have a hole made at the

top of the bend (some are made with a hole), and then you can carry up a ventilating pipe from it. If you have two ventilating pipes you must carry them to different heights, one not very high, and the other to a considerable height; but practically one is sufficient. Another thing that you can do—especially if the trap is in the basement of the house—you can make any waste pipe end in the side of it, through a hole in the side above the water, and yet below the cover, so that you do not get the place flooded if the holes in the cover are stopped up, as they are apt sometimes to be. This is a very convenient plan.

Sinks ought always to be against external walls. They almost always used to be built (and now often are) against internal walls. Their pipes have no more business to go straight into drains than the waste pipes of cisterns; they should always be carried out into the yard, and made to end over one of these traps, or else they should be carried into the side of it. The same thing is true of rain water pipes. Unless rain water pipes are constructed with the view of ventilating the sewer, and are made with proper joints, they ought to end *above* the traps.

We now come to the consideration of the disposal of a particular kind of refuse matter, namely, excretal refuse matter. I want first to prove to you that it is necessary to get rid of refuse matter generally, and especially so of this particular kind of refuse matter from the neighborhood of habitations. I could quote to you from any number of reports showing that the general death rate, and also the death rate from certain specific diseases, especially typhoid fever and cholera, depends to a very great extent upon the amount of filth, and especially of excretal filth, that is in and about the habitations of people.

Take the following opinion from the evidence given by Mr. Kelsey before the Health of Towns Commission (1844). When asked, "Does the state of filth and the effluvia caused by defective sewerage, by cesspools or privies, and decomposing refuse kept in dust bins, powerfully affect the health of the population?" he says, "Yes, it does; it always occasions a state of depression that renders persons more liable to be acted upon by other poisons, even if it be not the actual cause of it. The line of habitations badly cleansed, and in this condition, *almost formed the line of cholera cases.*"

Then, after a description of cellar dwellings, which are even now prevalent in some of our large towns—in this case referring to Liverpool—Dr. Duncan pointed out that the ward "where the largest proportion (more than one half) of the population resides in courts or cellars, is also the ward in which fever is most prevalent, 1 in 27 of the inhabitants having been annually attended by dispensaries alone;" and he remarks that "people do not die simply because they inhabit places called courts or cellars, but because their dwellings are so constructed as to prevent proper ventilation, and because *they are surrounded with filth*, and because they are crowded together in such numbers as to poison the air which they breathe."

Well, then, illness is caused if these refuse matters are not removed from the neighborhood of habitations, and illness with all its attendant misfortunes and difficulties.

Now what plans have been adopted for removing these matters from habitations? That is one thing to be considered; and another thing to be considered is, are these excretal matters of any value; can anything be done with them; and if so, how can the most be got out of them?

Now, if I tell you what their composition is, you will see at once that they must be of considerable value; and when you reflect that these refuse matters constitute a great proportion of the refuse matters of our bodies, you will see at once that they must contain the same elements as our food, and that therefore there is at any rate a possibility of their being used for the reproduction of food. Now, what is their composition? The results of a great number of analyses, which are, however, only sufficiently complete in the case of males of from 15 to 50 years of age, show that the mean amounts in ounces of the various constituents during 24 hours are as follows:

	Fresh Excrements.	Dry Substance	Mineral Matter	Carbon.	Nitrogen.	Phosphates
Fæces......	4.17	1.041	0.116	0.443	0.053	0.068
Urine......	46.01	1.735	0.527	0.539	0.478	0.189
Total....	50.18	2.776	0.643	0.982	0.531	0.257

[Paper read by Mr. Lawes, F. R. S., before the Society of Arts, March 7th, 1855.]

Now, what does that mean? Nitrogen and phosphates are the very things we get to use as manures, and we can from this chemical composition of the excreta calculate their relative and absolute value.

In the first place I want to point out to you that the amount of valuable matter contained in the urine in the 24 hours is considerably greater than that contained in the fæces in 24 hours. Now, that I tell you at once, in order that you may not run away with the fallacy that is sometimes indulged in that you may throw away the urine of a population so long as you retain the fæces, and that you will get the greatest amount of manure from the latter. On all heads the matters contained in the urine are in larger proportion than in the fæces, and especially as regards the important matters, *e. g.*, the nitrogen is about nine times as much.

To estimate the value, it is convenient to take amounts that are passed in a year, and it has been calculated that the average amount of ammonia—representing the nitrogen in the form of ammonia—discharged annually by one individual, taking the average of both sexes and of all ages, is about 13 lbs., or nearly that; and it has been estimated that the money value of the total constituents of the excreta is, in urine, 7s. 3d., and in fæces about 1s. 3d., giving a total of about 8s. 6d. a year, so that you see at once that the value of the urine is about six times as much as the value of the fæces. When you consider that about ten times more urine is passed (by weight) than fæces, you see that fæces are more valuable than urine, weight for weight, although the total fæces are much less valuable than the total urine. There is, then, no doubt about the value.

The next thing is, what are the plans that have been attempted for utilizing it? The earliest plan, and one that is defended by many up to the present day—and by many, I was going to say, who ought to know better—the earliest plan consists in keeping the fæces, and a certain small amount of urine for a longer or shorter period in or about the premises in some form or another. And there are two ways in which this can be done. It can be done, as it is in many towns even now, as it is notably in many continental towns, as Paris and Berlin and Vienna. It can be done either by keeping these matters in a semi-liquid state, in tanks or vessels prepared to receive them, and emptying these at certain times and taking their contents away to be used as manure, or it can be done by mixing these matters with certain refuse which will to some extent dry them ; and some such refuse is found in all houses, and is, to wit, ashes. Now, those are the two plans that have been adopted—I may almost say from time immemorial, at all events for a great many years—in order to collect this valuable manure; that is to say, by those who have made any attempt to collect it at all.

Let us take the first plan and consider it for a few minutes—the plan of digging a hole in the ground and throwing all this refuse matter into it. When this is done, unless the hole in the ground is impervious, a great amount of this refuse matter will percolate into the soil around, and get into wells. In certain towns this has been actually encouraged. There are certain towns where holes have been made to receive the refuse matters of the population in pervious sandstone strata, with the express, distinct, and avowed object of letting the liquid matters, and as much as possible of the solid matters, precolate the soil and get away as best they could. These dumb wells, as they are called, have been made and shut up

with the deliberate intention of not being opened for many years, and in certain places the soil has been so absorbent that when opened the wells have been almost invariably found empty. Now that plan need only be stated to be condemned. In all these towns the well water, which is often the only supply for the people, is largely polluted, and is in fact to a great extent supplied by these very dumb wells, which are often close by; and in almost every town where there is an epidemic of typhoid fever you find an inspector going down from the Local Government Board, and reporting that this is the case.

Now, the improvement on this bad plan, or want of plan, in places where it is not done away with, is to line the pits with cement, and to provide a drain from them into the nearest sewer. Thus the cistern becomes merely a pit in which to collect the solid matters, while you allow the liquid matters, which are the most valuable, and which are just as likely to become offensive, to run into the sewer. You collect the solid matter which is less valuable, and which is rendered still less valuable by having much of its valuable material dissolved out, by the liquid which is allowed to run away.

The other plan is to do as is done in Paris, to make these large cesspools (so large that they take six months, or even a year, to fill), under the houses or under the courts, to make them impervious, and not drain them at all. Of course the pits are only theoretically impervious, but practically very many of them certainly are not so. But, however, supposing that they are, they in any case requiring a ventilating shaft, or the foul air which collects in them will find its way through, somehow or other, and will poison the air of the house. Another danger is, that if they are not ventilated, and even sometimes if they are ventilated, the men who go into them may be suffocated by the poisonous gases accumulated in them.

The first of these plans, in which the liquid matters all run away, is confessedly a failure. You deliberately take and throw away all the most valuable part, and the part which remains is not only of no value, but is a distinct expense, because no one will take it away unless he is well paid for it, so that there is a very considerable loss on that system. And so the system cannot be called one of utilization. Then, the disadvantage of the Paris plan, apart from the general disadvantage of having such a thing as an immense cesspool underneath each house, is found in the emptying of them. This operation causes a fearful nuisance, even although they are now emptied by means of carts in which a partial vacuum is first created, so that when the hose is attached to the cart and placed into the pit the semi-liquid stuff rises up and fills the tonneau, as they call it. And then I may tell you, as a matter of fact—I could give you the figures—that the system does not pay; that the collection costs so much that the manure made from the stuff does not pay the cost of collecting.

Let us consider, now, some improved systems in which this manure is collected, mixed with ashes and household refuse, and sold in a semi-dry state, because this is a plan which has been very much defended of late. These plans are developments of the old midden—a heap in the yard at the back of the house, into which all kinds of refuse were thrown.

The first improvement, as in the case of the cesspool, was to make a kind of pit lined with cement. There are different contrivances employed. There is one which is known as the Manchester plan, and another known as the Hull plan, and so on; but in all the ashes are thrown into the pit, so as to make a semi-solid mass.

The conditions necessary for them are these:—In the first place they must receive no moisture from the soil around. In the second place, they ought to allow no liquid to escape from them, because, if so, they are confessedly failures. It is plain that the object of all these systems where the excretal matters are to be kept out of the sewers must be to separate them *entirely* from the sewage, because, if you do not, you have still sewage to treat. We have already seen that the water supply of the town goes into it to be soiled, and you require sewers to take it away. You have got, therefore, water which is, to a certain extent, dirty. The theory of persons who support those systems which I am now describing is that, if you prevent the most foul part of the refuse matters from getting to the sewers, you will not then

require sewers so large to begin with; and, also, that you will not require to treat the sewage afterwards, but will be able to turn it into a river without any disadvantage. Now, if these cesspools and these midden closets require to drain their liquid contents into the sewers, the sewage will certainly have to be treated just as much as if you were to allow the whole of the refuse matter of the town to get into the sewers; and that is proved by the fact that the sewage of towns where you have cesspools and midden pits drained into the sewers is considerably more foul, and is within a very little of being as strong, as the sewage of water closeted towns, so that it requires treatment at least as much as the latter does.

The next condition with these midden heaps is that they must secure, practically, as much dryness of the contents as possible; and then they require an efficient covering up of the refuse matters by the ashes that are thrown down, and that is done in various ways. Lastly, they require ventilating.

Now, with either of these systems, it is desirable to have the receptacle as small as possible; it is desirable for sanitary reasons, though not for economical ones, to have the receptacle as small as possible, so that as little of these matters shall be retained about the premises as possible. The midden closet used at Hull consists of an impervious receptacle, which is not sunk into the ground at all, but is, in fact, merely the space directly under the seat of the closet, the front board being movable, so that the scavengers can get the stuff when full. That, no doubt, is by far the best of these simple ash closets.

After this we pass on to a still greater improvement, to what you might call a temporary cesspool—that is to say, a simple tub or box placed underneath the seat to collect the excretal matters, these tubs or boxes being collected every day by contractors and their contents used for manure.

I may tell you at once that this is really the system out of which most is got in the way of profit. There is no doubt of it whatever. This is the system that has been practiced in China for thousands of years. It is the system which is practiced now in the neighborhood of Nice, where they grow orange trees and scented flowers, and where they grow a large quantity of things which require rich manure; and it is perfectly certain that it is the system in which there is least waste.

Now, this system has been very much revived of late in certain towns. In Edinburgh and Glasgow, and especially in many foreign towns — in Berlin, Leipsic, and in Paris — this is a plan which is adopted on a large scale. Of course, the difficulties of the system are enormous, and the nuisance is considerable. As far as the difficulties are concerned, I may tell you what Dr. Trench, of Liverpool, has calculated in regard to that town; he calculates that the space that would be required for the spare receptacles for the borough of Liverpool would be 11 acres, 2 roods, 32½ perches; that if put on a railway four-abreast they would extend a distance of 12 miles. Now, you see at once that a system which requires anything of that sort is not a system likely to be adopted for any large town. But, mind, there is no doubt whatever about this, that for small places it is an infinitely more healthy and more reasonable system in every way than either of the other two plans that we have considered. It is carried out with a simple bucket, in which the refuse matters cannot be allowed to remain for a long time, because it is not large enough, and because they would become too offensive. This system is evidently better for health than keeping the matters about the premises for a long time in any other form whatever. A variety of this plan is to be found in what are called the trough latrines that are used in many large manufactories. This simply consists of a trough which runs below a row of seats, which trough can be emptied into barrels by lifting a plug at the lower end; the stuff is taken away to farms.

There are two or three varieties of the tub or pail plan. One is known as the Goux system, and another as the Eureka system; these systems have been much praised of late. They are simply pail systems, in which some deodorizer or some absorbent is used. In the Goux system there is a sort of double pail, with an absorbent between the two pails; and the idea is to do away with some of the

offensiveness of the tub or pail system.

Now, I must say a few words to you about the dry earth system, which has been so much praised. In the first place I may tell you that sifted ashes are sometimes used instead of dry earth, because they are always at hand, and that there are several plans for the use of sifted ashes which are attempts to obviate the difficulties which are met with in the procuring of dry earth. It is found that when a sufficient quantity of dried and sifted earth, especially of particular kinds, is thrown upon refuse matters, that they are deodorized, and that they may be kept for a very long time without becoming offensive. The conditions are these : in the first place the earth must be dried, and in the second place it must be deposited on the refuse matters *in detail,* as it is called, that is to say, you must not take a great heap of excretal matters and throw a lot of earth upon it, but you must throw a little earth upon it each time the heap is increased by any more refuse matters. It is found, then, that about one pound and a half of dry earth is sufficient to deodorize the excretal matters that are passed at one time by an individual. With regard to the kind of earth, almost any earth will do except sand and chalk.

The next point is, that such earth may be used several times over. After it has been used once, it requires merely to be dried again and sifted, and you cannot tell it at sight at all after it has been used two or three times from that which has been used once ; you do not see any difference whatever ; all the organic matters and all the matters that would be offensive are entirely absorbed and rendered inoffensive to the smell, and so long as it is kept dry this earth remains quite inodorous.

There are all sorts of forms of closets, and so on, that have been contrived for utilizing dry earth in this way, but there is not the slightest necessity that I should describe these plans to you. I will therefore go on now to tell you of the results that have attended the application of this system at various places, and the advantages and disadvantages of the system. In the first place, with this system it is a *sine qua non* that no liquids are to be thrown into the earth closet, so that it is a system which does not provide for slops ; that is against it to begin with. Then if any liquids are accidentally thrown in, or if, as is the case in certain places, the air is exceedingly damp, or if the contents get moist in any way, you have, to all intents and purposes, a cesspool without its advantages, or without the special precautions that are commonly taken with regard to cesspools. That is another disadvantage of the system, we shall find more directly.

Now for the advantages. The advantages, perhaps, are best shown by giving some statements as to the working of the system at different places. At Broadmoor the lunatic asylum is supplied with earth closets. The water closets with which the place was originally supplied were done away with, and the earth closet system adopted. A mixture of earth and ashes is used, but the slops are allowed still to pass through the drains. Here, you see, you have got every advantage that such a system could have. You have sewers originally made by Mr. Menzies, made for the water closet system; and so they can send just what they like into them, and treat the earth closet in a sort of drawing-room fashion—if I may so call it—I mean give it its best chance.

Then at various schools it has been found to answer very well. The simplest form of it is a mere trough into which the refuse matters fall and into which earth is thrown. At various jails the plan has also been used with considerable advantage. At one place, where there was an attempt made to save all the fæces and urine of the boys in the school in this way, it was found that four pounds of dry earth a day* was required for each boy. I mention that to you to show you the absolute impracticability of doing a thing of that sort on a large scale. The expense, of course, would be enormous.

Where the plan has been used as a temporary arrangement it has, on the whole, succeeded very well, and especially so, for instance, at Wimbledon Camp. At Wimbledon Camp there is no doubt it has been an enormous improvement on the old system. Now you see at once that that was a temporary

* That would be 125 tons a week for a population of 10,000.

arrangement, that they could get plenty of earth, and so there was very little to be wondered at that a system which does, if it is properly carried out, deodorize offensive matters should have been there so far a success.

Now, I must tell you a little about the Indian experience. The Indian experience has been unfavorable to this system, but there are many statements made in Indian reports to the effect that it is a considerable improvement on some of the systems that were in vogue before. That you would easily believe if I read you a description of some of the systems, or, rather, of the want of system, that they had before they adopted this plan. The Army Sanitary Commission make the following statement:—"It is insufficient to remove only one class or cause of impurities, and to leave the others; and no sanitary proceeding which does not deal effectually with all of them can be considered as sufficient for health."

"The following sources of impurity require to be continually removed from inhabited buildings in India as elsewhere; (*a*) solid kitchen refuse including *débris* of food; (*b*) rain water which would if left in the subsoil tend to generate malaria; (*c*) all the water brought into the station except that which accidentally evaporates. This water is used for drinking, cooking, washing, baths and lavatories. The amount cannot be taken at less than twelve gallons per head for every healthy man, woman, and child, including servants; from thirty to thirty-five gallons per head for every sick man per day, exclusive of water for horses. . . . Practically, this water in all climates, but especially in India, becomes, if not safely disposed of, an inevitable source of disease and ill-health. It contains a large amount of putrescible matter, and if urine were mixed with it, it would become so noxious that it would matter very little whether or not the contents of latrines were added to this other sewage; (*d*) the matter from latrines, including solid and fluid excreta at about one pound per man per day, or, in round numbers, half a ton per day per thousand men."

Those are the matters which will require to be removed. Now the Commissioners go on to say that the solid *débris* being removed by hand or cart labor, the refuse water must "either be passed into cesspits, or it must be carried away, or it must be allowed to find an outlet where it can by surface drains—probably into the sub-soil."

Then, farther on, they say that the latrine matter, with which alone the dry earth system proposes to deal, "is to the fluid refuse of barracks, hospitals, cook houses, and so forth, as 1 to 190; that is, for every pound of human excreta removed under the dry earth system there are in every well regulated establishment about 190 of fluid refuse which must be otherwise disposed of." You see at once that this is absolutely condemnatory of the system for use in permanent barracks, and I think you will come to the conclusion that I have come to, namely, that it is a system that is only fit for temporary places, like the camp at Wimbledon. It is perfectly plain that it is absurd to have two systems, a system of sewers to carry away the foul water of a station—for that you must have—and another system for carrying away a certain portion of the excretal matter, which might all perfectly well be allowed to go away with the foul water.

As for the utilizing of it in this way, I do not believe in it at all. I mean to say that the cost of bringing in dry earth into a station, and especially into a large town, and then of carrying it away again, would be considerably greater than the money that would be got for the manure. You will see, and I dare say you have seen, that the manure collected under the dry earth system has been put down as worth all sorts of fabulous sums. Well, it is not worth anything of the kind. It is the greatest mistake to suppose so. The manure from the dry earth system is a good garden soil, and it is not anything more. It is not a manure. And this earth that has been passed three times through the closets is nothing more than that, as you will see in the report of the British Association Sewage Committee. In that report there are given the results of analyses of the earth after passing once, and after passing twice, and after passing three times through the closet, and it is said that after passing three times through it is nothing more than a rich garden soil, and it will not pay for in-

curring the expense of carriage to a long distance; so that the utilization question is certainly not met by the dry earth system. This is what I wanted to come to.

I may as well tell you that it has been attempted to apply this system to a town. One part of Lancaster is supplied with dry earth closets, and there are several villages in which it has been tried. In villages it seems to answer very well when looked after, In a town, for some of the reasons that I have given you, it fails. There is no doubt about that.

That will finish our consideration of the systems which propose to separate the excretal refuse as if it were something totally, and entirely, and essentially distinct from all other refuse matter forming the sewage of a town. Those systems all go upon a wrong principle. This refuse matter is dangerous to health, and those systems, one and all, go upon the principle that these matters may be retained in and about houses as long as possible, so long as they do not create a nuisance, or so long as they are not felt to be a nuisance. Now that position is obviously wrong. All these systems depend upon leaving such matters as long as possible about the houses. The object of them all is to produce a certain result with as little expense as possible. It is perfectly plain that the longer this refuse matter is left about houses, under all these systems,—I do not care which one you take,—the cheaper the plan will be carried out, so that there is a tendency in all these systems to leave dangerous refuse matters about premises for a very long time. Now, the answer is that they are perfectly deodorized or disinfected, as the case may be. The answer to that is—if your system is perfect, they are deodorized in some cases; for instance, in the dry earth system they are deodorized. But if they are not, all the danger arises that could arise from any other of the bad systems I have described to you. Then, again, the fallacy is entertained that deodorization and disinfection mean the same thing. It is certain they do not. We know quite well that the dry earth system deodorizes refuse matters. They do not putrify and cause offensive smell after deodorization, but we do not at all know that that system disinfects matters; and there is not the slightest reason for supposing that this earth, if at any time rendered moist,—and we do not know whether or not disinfection takes place even when dry,—that this earth may not then be dangerous and have infecting properties. I mean to say we do not know that the excreta of cholera patients, or typhoid fever patients are disinfected, as well as deodorized, by this mixture with dry earth, and so I think you will all agree with me that the plan which has for its principle the removal of these excretal matters immediately from the vicinity of hibitations (utilizing them afterwards, if possible), that the plan which goes upon the principle of removing them in the cheapest way possible, viz., by water carriage and by gravitation, removing them at the same time with all the other refuse matters of the population (with the single exception of the ashes), I think you will agree with me that that is, after all, the most reasonable plan. And I do not hesitate to say that nothing has contributed so much to lower the death rate of towns as the introduction of the water carriage system.

The tunnel which has been bored under Durdham Down, and which as forming one section of the works of the Clifton Extension Railway will put the Great Western, Midland, and Bristol and Exeter systems into direct communication with the Channel Docks at Avonmouth, being now completed, was passed through by the Mayor of Bristol, Mr. C. J. Thomas, and a number of citizens interested in the Docks and railway extension. The length of the tunnel is 1737 yards, and the gradient throughout 1 in 64. It has been bored through rock of the hardest description, every foot of which had to be blown away; about 104,000 cubic yards or 250,000 tons of rock had to be got out. Mr. W. J. Lawrence, who is constructing the Channel Docks, was the contractor for the work, but the boring of the tunnel was sublet to the Machine Tunneling Company, and has been carried out under the personal superintendence of their representative, Mr. Bell, C. E. It is expected that Colonel Yolland will make the official inspection of the tunnel and line.

THE INDIAN TRIGONOMETRICAL SURVEY.

From "Nature."

One does not usually expect to find much of general interest in the Report of a Trigonometrical Survey. Col. Walker's admirably drawn-up Report, however, includes some matter of more than special value; indeed, many of the details connected with the immediate work of the Survey are calculated to interest the general reader, they are concerned to such a large extent with the peculiar difficulties to be overcome by the various parties, difficulties which make ordinary survey work look like mere child's play.

The Index Chart prefixed to the Report enables one to form a very full idea of the work which has already been done, and of how much there is yet to do. From Cape Comorin to Peshawur and all along the Himalayan frontier, and from Kurrachee on the west to Burmah on the east, the country is covered with an intricate net-work of triangulation, including, however, many gaps which will take many years to fill up. Shooting out from the northern border of the system of triangulation are numerous aurora-like lines indicating the secondary triangulation to fix the peaks of the Himalayan and Sooliman ranges. We cannot go into the details of the work of the Survey, and must content ourselves with a brief summary of the out-turn of work during the year under review, and with a reference to a few of the more interesting side topics.

Of Principal Triangulation, with the great theodolites of the Survey, seventy triangles, embracing an area of 7,190 square miles, and disposed in chains which, if united, would extend over a direct distance of 302 miles, and in connection with which three astronomical azimuths of verification have been measured. Of Secondary Triangulation, with vernier theodolites of various sizes, an area of 5,212 square miles has been closely covered with points for the topographical operations, an area of 3,650 square miles has been operated in *pari passu* with the principal triangulation but exterior thereto, and in an area of 12,000 square miles—in the ranges of mountains to the north of the Assam Valley which are inhabited by independent tribes — a large number of peaks have been fixed, many of which have already been found serviceable in the geographical operations now being carried on with the military expedition against the Dufflas. Of Topographical Surveying, an area of 534 square miles has been completed in British portions of the Himalayas, on the scale of one inch to the mile, an area of 2,366 square miles in Kattywar on the two-inch scale, and areas of 690 and 63 square miles respectively, in Guzerat and in the Dehra Dun, on the scale of four inches to the mile. Of Geographical Exploration much valuable work has been done in Kashgharia and on the Pamir Steppes, in connection with Sir Douglas Forsyth's mission to the Court of the Atalik Ghazi, and several additions to the geography of portions of the Great Thibet and of Nepaul have been obtained through the agency of native explorers.

In the course of the operations of the year under review the northern section of the Brahmaputra Meridional Series has been completed whereby two important circuits of triangulation formed by it with the Assam and East Calcutta Longitudinal Series to the north and south, the Calcutta Meridional and the Eastern Frontier Series to the west and east, have been closed. The Straits of the Gulf of Manaar have been reconnoitered, with a view to connecting the triangulation of India with that of Ceylon, which has been found to be feasible.

Probably the most important features in the operations of the principal triangulation of the year are the resumption of the chain of triangles in Burmah, and the completion of the Bangalore Meridional Series for the revision of the southern section of the Great Arc.

Referring to the revision of certain important triangulations which were originally executed at the commencement of the present century with very inferior instruments, Colonel Walker expresses his conviction that no portion of the principal triangulation remains which will ever require to be revised, and that

the last of the old links in all the great chains of triangles which might with any reason have been objected to as weak and faulty, have now been made strong and put on a par with the best modern triangulation.

The pendulum observations have been completed, and the final results are now being computed and prepared for publication.

Considerable assistance was, moreover, rendered to Col. Tennant in the operations connected with the observation of the Transit of Venus; the Appendix contains Mr. Hennessey's account of his observations at Mussooree, the details of which have already appeared.

The reports of the various district superintendents are very full, and contain a good deal that is of general interest; the accompanying district sketch-maps are of great use in enabling one to read these reports with understanding. We shall briefly refer to some of the points of more general interest.

In Major Branfill's report on the Bangalore Meridional Series, a very interesting phenomenon is noticed in connection with the Cape Comorin base-line. The operations of 1873–74 were intended to close in a side of the polygon around the base-line which had been completed in 1868–69; but it was found that one of the two stations on the side of junction had disappeared. This station was situated on a remarkable group of Red Sand Hills, where, in 1808, Col. Lambton had constructed a station by driving long pickets into the drift sand; in 1869, Major Branfill, finding no trace of these pickets, had caused a masonry well to be sunk to a depth of ten feet, where it reached what was believed to be firm soil below; but during the interval of four years this well had been undermined, and nothing remained thereof but some scattered *débris*. It would appear that the sand hills travel progressively in the direction from west-north-west to east-south-east, which is that of the prevailing winds in this locality; if Col. Lambton's station was situated on the highest point of the hills and in a similar position relatively to the general mass as Major Branfill's, then the hills must have traveled a distance of about 1,060 yards to the E.S.E., for the results of the triangulation show that this is the distance between the positions of the two stations; thus the rate of progression would be about seventeen yards per annum. From Major Branfill's Notes on the Tinnevelly district, which are appended to the General Report for 1868–69, it appears that certain measurements of the eastward drift had made it as much as 440 yards in the four years 1845–48; but the distance between the trigonometrical stations of 1808 and 1869 probably affords the most accurate measure which has hitherto been obtained of the rate of progress of this remarkable sand-wave, which gradually overwhelms the villages and fields it meets with in its course, and has never yet been effectually arrested; numerous attempts have been made, by growing grass and creepers and planting trees on the sands, to prevent the onward drift, but they have hitherto been unsuccessful.

Mr. Bond, one of Major Branfill's staff, managed to procure an interview with a couple of the wild folk who live in the hill jungles of the western Ghats, to the southwest of the Palanei hills. A strange dwarfish people had often been heard of as frequenting the jungles near the station of Pemalei, in the north-west corner of the Tinnevelly district, but until Mr. Bond caught these two specimens no trace of them had been seen by the members of the Survey. These two people, a man and a woman, believed themselves to be 100 years old, but Mr. Bond supposes the man to be about twenty-five, and the woman 18 years of age. "The man," Mr. Bond states, "is 4 feet $6\frac{1}{2}$ inches in height, $26\frac{1}{4}$ inches round the chest, and $18\frac{1}{2}$ inches horizontally round the head over the eyebrows. He has a round head, coarse black, woolly hair, and a dark brown skin. The forehead is low and slightly retreating; the lower part of the face projects like the muzzle of a monkey, and the mouth, which is small and oval, with thick lips, protrudes about an inch beyond his nose; he has short bandy legs, a comparatively long body, and arms that extend almost to his knees; the back just above the buttock is concave, making the stern appear to be much protruded. The hands and fingers are dumpy and always contracted, so that they cannot be made to stretch out quite straight and flat; the palms and fingers are covered with thick

skin (more particularly so the tips of the fingers), and the nails are small and imperfect; the feet are broad and thick skinned all over; the hairs of his moustasche are of a greyish white, scanty and coarse like bristles, and he has no beard.

"The woman is 4 feet 6½ inches in height, 27 inches round the chest (above the breasts), and 19½ horizontally round the head above the brows; the color of the skin is sallow, or of a nearly yellow tint; the hair is black, long and straight, and the features well formed. There is no difference between her appearance and that of the common women of that part of the country. She is pleasant to look at, well developed, and modest." Their only dress is a loose cloth, and they eat flesh, but feed chiefly on roots and honey.

"They have no fixed dwelling places, but sleep on any convenient spot, generally between two rocks or in caves near which they happen to be benighted. They make a fire and cook what they have collected during the day, and keep the fire burning all night for warmth and to keep away wild animals. They worship certain local divinities of the forest, Rakas or Rakari, and Pe (after whom the hill is named, Pe-malei)."

The woman cooks for and waits on the man, eating only after he is satisfied.

The means taken for tidal observations in the Gulf of Kutch promise to lead to valuable results. The object of these observations is to ascertain whether secular changes are taking place in the relative level of the land and sea at the head of the gulf. Very great difficulties were found in selecting suitable stations for fixing the tide-gauges, as the foreshores of the gulf consist mainly of long mud-banks, which often stretch miles into the sea, and are left bare at low water, when they are intersected by innumerable tortuous and shallow creeks, whose shifting channels would be very unfavorable positions for tide-gauges. Only three points suitable for tidal stations were met with on the coasts of the gulf: at Hanstal Point, near the head of the gulf; at Nowanar Point, half way up, on the Northern or Kutch coast; and at Okha Point, on the southern coast, opposite the island of Beyt. None of these points, however, are situated in ports or harbors, where piers, jetties, landing-stages, or docks might have been utilized; on the contrary, they are all situated at some distance from the nearest inhabited localities, and present no facilities whatever. The operations had thus to be of the very simplest nature. The only practicable plan was to have the tide-gauges set up on shore, over wells sunk near the high-water line, and connected with the sea by piping. The wells are iron cylinders, with an internal diameter of twenty-two inches, which slightly exceeds the diameter of the float; the cylinders were made up in sections of fifty inches in length, the lowest of which is closed below with an iron plate, and the whole, when bolted together, forms a water-tight well, into which water can only enter through the piping for effecting connection with the sea. The piping is of an internal diameter of two inches, which has been computed to be sufficient to permit of the transmission of the tidal wave to the well without sensible retardation. Iron piping is laid from the well to the line of low water; it is brought vertically up from the bottom of the well nearly to the surface of the ground, and is then carried down to the sea, where flexible gutta-percha piping is attached, and carried into the deep water. The outer piping terminates in a "rose," which is suspended a few feet above the bed of the sea by a buoy, in order to prevent the entrance of silt as much as possible, and it can be readily detached from the iron piping whenever it has to be cleaned.

After many difficulties, and even dangers to life, Capt. Baird's party managed to get the gauges erected and set to work, and what with the tidal observations, observations of the barometric pressure, the velocity and direction of the wind, and the amount of rainfall—for each station has been provided with means for making such observations—very valuable results may be expected.

Lieut. Gibbs' notes on the portion of the Dang Forests, in the Guzerat district, visited by him in 1874, are of great interest, and we regret that space forbids us referring to them in detail. His observations on the inhabitants of this region are of special value; he also seems to have paid considerable attention to the fauna, flora, and geology of the district.

Capt. Heaviside's lively narrative of the pendulum work in India, of his journey home, and of the operations at Kew, will also be read with interest.

Two narratives of somewhat unusual interest are given in the Appendix. One of these, by Lieut.-Col. Montgomerie, gives an account of a journey to the Namcho or Tengri Nur Lake, in Great Thibet, about ninety miles north of the Brahmaputra, by a native explorer, dur- 1871–72. The explorer was a semi-Thibetan, a young man who had been thoroughly trained for the work, and who was accompanied by four assistants. The party set out from Kumaon in November, and crossed the Brahmaputra at Shigatze, and amid considerable hardships made their way northwards, reaching the lake about the end of January, when they found it completely frozen over, although the water is so salt as to be unfit for drinking. The party intended to travel all round the lake, which is 15,200 feet above the sea, fifty miles long and from sixteen to twenty-five miles broad, and intended to proceed further to the northward and take complete surveys, but were robbed of nearly all they had, and were thus compelled to beat a rapid retreat, which they did by way of Lhasa.

During the greater part of his journey to the Namcho Lake the explorer found the streams all hard frozen, and he was consequently much struck by the number of hot springs which he met with, and more especially by the great heat of the water coming from them, his thermometer showing it to vary from 130° to 183° Fahrenheit, being generally over 150°, and often within a few degrees of the boiling point, being in one case 183° when the boiling point was 183¾°. The water generally had a sulphurous smell, and in many cases was ejected with great noise and violence; in one place the force was sufficient to throw the water up from forty to sixty feet. These springs in some respects seem to resemble the geysers of Iceland.

To the south the lake is bounded by a splendid range of snowy peaks, flanked with large glaciers, culminating in the magnificent peak "Jang Ninjinthangla," which is probably more than 25,000 feet above the sea. The range was traced for nearly 150 miles, running in a north-easterly direction. To the north of the lake the mountains were not, comparatively speaking, high, nor were there any high peaks visible further north as far as the explorer could see from a commanding point which he climbed up to. He only saw a succession of rounded hills with moderately flat ground in betwen them. Immediately north he saw a lake of about six miles in length, which he was told was called Bul Cho, from the borax (bul) which is produced there in large quantities, supplying both Lhasa and Shigatze with most of the borax that they require.

The Tengri Nur or "Namcho" Lake is considered to be a sacred place, and although at such a very great distance from habitations and so high above the sea, it boasts of several permanent monasteries and is visited by large numbers of pilgrims. There are several islands in the lake, two of them large enough for monasteries: at the time the explorer was there the Lamas on the islands kept up their communication with the shore by means of the ice, but he did not hear as to what was done in summer. Fish are said to be abundant, and modern lake shells were found on the shore as well as fossil shells, which were very numerous and of all sizes.

The narrative contains many other valuable observations made on the people and the country through which he traveled; there is a good map of the route.

The other narrative is quite equal in interest to that just referred to. It consists of extracts from a native explorer's narrative of his journey from Pitoragarh in Kumaon *via* Jumla to Tadum, and then down through Nepaul, along the Gandak River, to British territory. The explorer, who had to exercise much determination and ingenuity, took minute notes by the way of all he saw, and has added much to our knowledge of the geography, the people, and the products of a region comparatively unknown. He had to cross many rivers by the way, which was generally done by means of ropes suspended between the banks. The explorer wished to proceed much further than Tadum, which is a little beyond the Brahmaputra, in Great Thibet, but was prevented by the head man of the village. He started on July

1, 1873, and reached British territory again about the end of November, after having traveled nearly 500 miles. We have space to notice only one interesting phenomenon which he observed. At Muktinath, near Kagbeni, about 11,280 feet above the sea, in N. lat. 29° and E. long. 83° 45′, about 600 feet south of the temple, is a small mound with a little still water at its base, having a sulphurous smell. From a crevice in this mound, at the water's edge, rises a flame about a span above the surface. The people of the place told the explorer that the water sometimes increases in quantity sufficiently to flow into the crevice; the flames then disappear for a while, and there is a gurgling noise, a report, and the flames burst up and show again. This spot is called Chume Giarsa by the Bhots.

Our readers will see, from the cursory glance we have been able to take at this Report, that it contains much valuable matter apart from the immediate work of the Survey, the members of which are doing good service to India and to science.

IRON AS A CONSTRUCTIVE MATERIAL.*

From "The Architect."

It is only of late years that iron, as compared with other metals, has been used as a constructive material, but it was known and employed for various other purposes from the very earliest times; and though it is now the metal of all others the most frequently used by, and is the best adapted of any to the requirements of, the architect or engineer, it is, as I say, comparatively recently that its great value for building and constructive purposes has been fully appreciated, and, to a certain extent, utilized; and it is with the hope of showing that it may be employed in a still better manner than at present, I venture to take up your time this evening.

Though the use of iron by architects in building structures has enormously advanced, the credit of discovering and applying the great advantages that iron unquestionably possesses over almost every other material to constructive purposes, is due, I think, to the engineers and not the architects. Architects as a body have neglected and slighted this universally useful metal, either rejecting it altogether, or employing it as it were under protest, and as if they were ashamed of it; they use it in fact as a drudge, and not as I venture to think they should, as a valuable friend, equal indeed to most other building materials and superior to some; valuable both for constructive and decorative purposes, and I apply these terms in the same sense as we employ them when speaking of wood, stone, or any other material we use in building; and while it is remarkable that we should have thus neglected it, the way in which engineers seized it is no less remarkable, for they with wonderful acuteness brought their science and practical knowledge to bear upon it, producing results that ought to be an example to us; for, as a rule, engineers, with regard to brick or stone, pay us the compliment of copying as well as they can our architectural forms and practice; but with respect to iron the reverse is the case, as they, finding that architects had done, I will not say could do, little or nothing with it, struck out a path for themselves, and it cannot be denied, have achieved in it a great success. I think, however, it is unfortunate to some extent that they did so, for it is in a great measure the cause of the want of appreciation iron obtains from architects, not because architects are jealous of the success of the engineers, but rather because of the disgust they feel at the inartistic result of their labors. Can this be remedied, and can iron be placed in its proper position with regard to architecture? I venture to hope it may, by taking advantage of the practical skill and knowledge which engineers have already obtained, and upon the foundation laid by them, advancing step

* A paper read before the Royal Institute of British Architects by Mr. C. H. Driver.

by step, till we succeed in finding uses for iron both in construction and decoration, which, while perfectly adapted to the material, will yet combine and harmonize with those we have heretofore had in use.

Let us consider for a moment some of the principal attributes of iron, and then see how architects generally take advantage of them. As regards wrought iron—first, it is very strong, bearing a working tensile strength of from five to six tons, and a compressive strain of from four to five tons per inch of section, and as regards strength it is as twenty-seven to five as compared with oak, and as twenty-seven to four as compared with fir, and yet if it is employed as a beam or girder, it is generally so swaddled up with cradling and lath and plaster, that as much room is taken up by it as if it had been a beam of oak or fir. Then again it is very light as compared with its strength, but by the same process at last mentioned, its weight is brought up to that of a wood beam. It is very ductile, easily hammered to any variety of shape, and yet almost the only form ever given to a wrought iron girder when used in building, is that of the ordinary rolled or plate girder.

Again, iron, though very durable, is not an imperishable material, and this appears to be practically forgotten, for though, unlike wood and perhaps stone, it is free from internal deterioration, yet it is liable to serious destruction by rust and oxydation of its outer surfaces, a most important point considering the fact that but little excess of material is usually provided than is absolutely necessary for the required work, and therefore it would be but reasonable to suppose that when used arrangements should be made by which all parts of a girder or column could be readily inspected; but in the system in vogue the reverse is the case, for the girder is so covered and hidden up that no inspection is possible, nor can any means be taken to paint or otherwise preserve it from the inevitable destruction that must result from rust. It is almost the same as regards cast iron; it is a material admirably adapted for columns, from its fitness to bear great compressive strains, and by its very nature capable of assuming almost any form that architects may design, from a plain column to the most elaborate effort of ornamental art the mind can conceive, yet as ordinarily employed the cast-iron column is either a plain round shaft with a square cap and base-plate with gusset-pieces to strengthen their connection with the shaft, or as a story-post like a girder standing up on end; this column or story-post is often covered with lath and plaster, and appears in the glorified shape of a Doric, Ionic, or Corinthian column, with cap, &c., to match, or as is the case in most shops, it is left in its native bareness behind a plate-glass front.

I repeat that we are glad enough to make use of the strength, lightness, and adaptability of iron, but we are ashamed to acknowledge that we have employed it, and therefore cover and hide it up; and I think this arises in a great measure from the idea (a mistaken one, however) that iron does not accord with other materials, and is unsuited for architectural forms, and, therefore, if we use it (as at the present time we are almost compelled to do) we should do our best to hide it up as much as possible; and it is argued that it is necessary to lath, plaster, and case it up to satisfy the eye, as from its strength so little is required that no effect can be obtained in using it, and, therefore, it is better to cover it up with other materials to avoid the thinness and poverty of appearance that is produced when employed alone, in the same way that the flesh covering the bones produces a beautiful form, and at the same time hides a ghastly skeleton. But does the hiding up of iron by other material meet the object intended, viz., better effect? (and setting aside for a moment the principle of honesty of construction) is not the result obtained most unsatisfactory? For owing to the introduction of iron much larger spaces are bridged over without requiring columns and arches than heretofore, and hence there is produced a bareness and an apparent weakness anything but satisfactory to the eyes. As an example, I will take that most familiar one to all, the shop front; there, as a rule, we have a structure of three, four, or more stories high, with elaborate and massive architectural features, columns, cornices, pediment, &c., piled up with lavish richness, all carried apparently by a stone lintel

of twenty, thirty or forty feet span, and of an absurdly little depth in proportion to what in appearance it has to carry over a huge field of plate glass ; while, as we all know, the real work of supporting the fine front is done by the wrought or cast-iron girder, which is hidden behind the stone fascia aided by cast-iron columns or story-posts, as the case may be. The effect is not pleasing or satisfactory for it is untruthful, and I contend that if the money spent upon the sham lintel that forms the casing to the girder were spent upon the girder and column by making them pleasing in design and form, the effect would not only be much better but positively good, for though we should still have the wide span and the plate glass under as before, yet we should see how the building above was really carried, and as we know that iron is strong and capable of doing its work, the eye as well as the mind would be satisfied.

With regard to this point, viz., the satisfaction of the eye, it is possible that the eye may require some amount of education before it becomes accustomed to the use of iron and its employment in connection with other material. For we are so accustomed to see beams, columns and brackets of certain proportions that we are at first sight shocked at the idea of detached columns of twenty-five or thirty diameters carrying great loads, or slender beams carrying a heavy building ; and it is difficult to adjust their proportions with the styles of architecture we have in use. But I have hopes that architects will, if they give the matter their earnest attention, with the sincere desire to succeed, produce designs for iron which, though not perhaps exactly in accordance with any existing particular style, shall yet harmonize, even perhaps by contrast, with them. Iron sometimes meets with other but very different treatment from the hands of architects, and I hardly know which is the worst, for instead of being hidden, it is brought prominently forward, but then not as iron, but something else, such as stone or wood, especially so in the case of cast-iron, for not only is it made to represent the last-named, but it also appears in the guise, or rather disguise, of wrought iron. I may instance balustrades, vases, parapets, tracery, &c. A prominent example of its misuse in this way is seen in the parapet and spandrels of Westminster Bridge, though happily, however, these were not the work of an architect.

There is, I think, another reason why architects as a rule ignore iron as a constructive material, and that is perhaps the most general one, viz., few of them comparatively know anything about it, never studying or looking upon it other than as the aforesaid useful drudge, and this more especially so with respect to wrought iron, and as to cast, they may perhaps use it for columns, railings, finials, or rain-water gutters and spoutings, but these they take ready designed from an ironfounder's catalogue, and they may, or which is more often the case, may not harmonize with the rest of their design, they thinking it is not worth their while to take the trouble to design such things for themselves. Or if they want a wrought-iron girder, they are, perhaps, able to work one out from the simple formulæ given in the various handbooks ; or, as is more likely, they leave it to the builder's foreman. But if the quantity required is large, and the work important, they then employ an engineer to work out the calculations, and as the engineer (with every respect to him) cares nothing about art, but a great deal as to whether his girders are strong and economical, it is very probable that the resultant work is ugly, and as without doubt the ordinary plate girders and columns, used in buildings generally, are ugly, the architect naturally enough covers them up with a material he does know something about, and therefore can design in ; but if the architect did know and understand as much about iron he would calculate for himself, and study to so design his girders or columns, or whatever else he may require, that the result should be artistic and suitable to the structure for which it was intended.

Surely architects, if they will, can so design their girders in wrought or cast iron that they shall be pleasing and effective. Let them but take the trouble to draw them out and calculate them for themselves, they will soon find it easy enough to arrange flanges, webs, cover plates, angle and tee irons so symmetrically as to be pleasing, and still preserve

the necessary scientific proportions and the relation of the several parts to each other in a practical manner—plates and angle and tee irons are now rolled in such length that very large spaces may be spanned by girders without any cover or junction plates being required. As for instance, plates can be obtained from 20 to 25 feet long by 2 to 3 feet wide; angle and tee irons up to 30 or 35 feet or even 40 feet. Many varied forms and even mouldings could and would be rolled, if manufacturers found there was a demand for them, and that it would pay to make the necessary rolls.

Reverting for a moment to the point that the constructive employment of iron is of comparatively late date, it is worthy of remark the significant fact that the artists of the Middle Ages had brick and stone and other materials, but no iron—at least not in quantities they could make structural use of, and they made such good use of the materials they had that we are feign to copy them. Is it not therefore fair to suppose that if they had had iron at their command as we have, they would have produced works in that material as admirable as are their works in others? and I am justified in assuming this from the wonderfully beautiful works they achieved in the ornamental wrought-iron work they did make. I cannot help, therefore, feeling that, to a certain extent, the poor results we have accomplished with all the facilities we have at our command is not a cheering instance of the progress of true art in these modern times.

There is yet another matter closely connected with iron as a constructive material which requires attention, and that is the relative positions in which wrought and cast iron should be placed, viz., whether in internal or external work, and this more especially applies to ornament. Now it is a certain and well-known fact that wrought iron is much more susceptible to the influence of weather as regards oxydation than cast, and though, therefore, there can be no question as to the superior art and beauty of wrought iron, yet it is a matter worthy of some consideration, if it be not more advisable, for the sake of durability, to employ cast iron for ornamental work externally, and confine our use of wrought iron to purposes of internal decoration. I am perfectly aware that in advocating the use of cast iron ornament at all I am touching upon dangerous ground, as I know that among many of the highest authorities there is a strong feeling against it, but be this as it may, the fact remains the same that cast iron is better adapted for external work than wrought, and I am inclined to think that the feeling which undoubtedly does exist against it is due to the way in which it is misused, and that if the design is properly adapted to the material one of the principal objections to its application is removed. I know it is said that cast iron ornament is inartistic, showing no feeling, utterly wanting in individuality, and vulgar in the extreme, so that cast iron ornament has almost become a by-word; but surely it is unfairly treated, for might not the same be said of work in bronze? A work in cast iron requires to have a model prepared and a mould made, so also does a work in bronze. The iron has to be melted and run into the mould, and it is the same with bronze; if the model is badly designed and badly executed in either case, the resultant cast will be bad also.

With respect to iron as a constructive material, the different qualities of the metal used is a very important and serious point, much more so than at first sight appears; for, as in the case of cast iron, there is not only a great difference of strength in the different brands, but also in the same iron, from the manner in which it is manufactured, and it is almost impossible to judge by the outward appearance of a casting whether the iron used is good or bad, for even when fractured it requires great skill and experience to do so. I do not, however, purpose to go into this matter this evening.

Hitherto I have only spoken of matters which concern iron as a building material, but I propose, with your permission, before closing my Paper, to add a few remarks upon constructive ornamentation of ironwork, or, as it would perhaps be better to put it, the ornamental construction of ironwork; for, though in my previous remarks, I have several times referred to ornamental work in iron, it has been irrespective of its being constructive or otherwise. I can, however, only give a passing glance

at it, for the subject is one which in itself would extend to almost any length.

We most of us know what ornamental construction consists of in wood or stone as opposed to constructing for ornament, but it is, I confess, difficult to apply the principles which guide us in the last-named materials to iron; for though it is true we can, as I have said, so arrange our tee and angle irons, webs and plates, &c., that they shall be symmetrical, that is not all that is required, for true ornament does not consist in symmetry alone, though symmetry is a very important element in it. We are placed in this difficulty, that almost any ornament we employ on constructive ironwork has to be itself constructed, thus flying in the face of that golden rule of ornament which tells us to "ornament our construction and not to construct for ornament." When working with wood and stone and some other building materials we can build in blocks or masses of material, and cut and carve them as it seemeth to us best, and it can hardly be said that we are able to do this in the same sense in iron; but though we cannot carve it, we can stamp, emboss, engrave, and even mould it if we will, for machinery is now so powerful that mouldings, splays, chamfers, &c., can be executed in this material with nearly the same facility as in wood; and there is some ground for consolation in the fact that whatever difficulties we may have to encounter with respect to having to construct for ornament in iron, the same difficulty has to be met with in respect to all other metals, and I am inclined to take advantage of "there being no rule without an exception," and make that exception in favor of iron and all other metals; but though we may have in some measure to construct our ornament, I think we should be careful to so manage it that the ornament we do employ shall not be wholly useless, and that if it does not add much to the strength of the structure it shall not at least be detrimental, and, therefore, all added ornament in ironwork should I think be of the very lightest description, and if not actually constructive, it should at least grow naturally from, and appear to be part of, the real constructive portion of the work.

Time, however, will not permit to go further into this point, which is in itself a sufficient subject for a paper, which at some future time I may ask to be allowed to read.

Allow me, in conclusion, to thank you for your attention, and at the same time to request your kind indulgence for much that I have said. Many of you, as I know, have already by your works anticipated my ideas with respect to constructive and architectural ironwork; and to you, therefore, my remarks, I fear, have been tedious. But still, I hope, you will endorse my views, as I have been encouraged to maintain them by the knowledge that, among those who stand the highest in our profession, there are some who have not thought it beneath them to design in iron, and with successful results—pardon me, if I mention the name of one, our honored President, Sir George Gilbert Scott.

REPORTS OF ENGINEERING SOCIETIES.

THE NEW YORK SOCIETY OF PRACTICAL ENGINEERING held its third quarterly session for the year 1875, in Cooper Union, on the evenings of September 7th, 8th, 9th and 10th. The President, James A. Whitney, delivered the annual address on the evening first named. Subject—"The relation of Patent Laws to American Agriculture, Arts, and Industries." At the subsequent meetings other elaborate papers were read; on the "Minor Economies of Manufacturers," by James C. Bayles, editor of the *Iron Age*; on the "Industrial Uses of Blast Furnace Slag," noticed elsewhere in our columns, by Frederick A. Luckenbach, M. E.; on "Steam Propulsion on Canals," by George Ed. Harding. Briefer essays were also read; on "Stationary Fire Extinguisher Pipes," by Henry Palmieri, M. E.; and on the "Testing of Water Pipes and Mains," by Ernst Bilhuber, M. E. The President's address has been published in pamphlet form by the Society. The next session will be held the latter part of November next.

INSTITUTION OF CIVIL ENGINEERS. — The council of the Institution of Civil Engineers have awarded the following premiums:—Telford medals and Telford premiums to the following gentlemen:—to Mr. W. Hackney, for his paper on "The Manufacture of Steel;" Mr. H. E. Jones, for his paper on "The Construction of Gasworks;" Mr. A. R. Binnie, for his paper on "The Nagpur Waterworks;" Mr. G. F. Deacon, for his paper "On the System of Constant and Intermittent Water Supply, and the Prevention of Waste;" Telford premiums to M. J. Gaudard, of Lausanne, for his "Notes on the Consolidation of Earthworks;" to Professor Prestwich, for his paper "On the Origin of the Chesil Bank;" to Mr.

J. T. Smith, for his paper "On Bessemer Steel Rails;" to Mr. C. Colson, for his "Details of the Working Tests and Observations on Portland Cement;" to Mr. T. C. Watson, for his "Description of the Use of Facines in the Public Works of Holland;" a Watt medal and the Manby Premium, to Mr. J. C. Hawkshaw, for his paper on "The Construction of the Albert Dock at Kingston-upon-Hull." The Council have likewise awarded the following prizes to students of the Institution:—Miller prizes to the following gentlemen:—Mr. A. E. Baldwin, for his paper on "The Design and Construction of Lock Gates;" Mr. J. C. Inglis, for his paper "Experiments on Current Meters and their Bearing on the Hydraulics of Rivers;" to Mr. W. B. Myers, for his "Comparison of the various forms of Girder Bridges, showing the Advantages of the Schwedler Bridge; together with an elucidation of the Theoretical Principles of the same;" Mr. A. S. Moss, for his paper on "The River Humber;" Mr. W. P. Orchard, for his paper on "Hydraulic Calculations relating to Water Pressure and Walls to resist it, Gauging of Water, the Flow of Water in open Channels and in Pipes;" Mr. J. Tysoe, for his paper on "The Manufacture of Illuminating Gas from Coal;" Mr. J. C. Mackay, for his paper on "Concrete." The following note has also been issued by the Council:—"It has frequently occurred that in papers which have been considered deserving of being read and published, and have even had premiums awarded to them, the authors may have advanced somewhat doubtful theories, or may have arrived at conclusions at variance with received opinions. The Council would, therefore, emphatically repeat, that the institution must not, as a body, be considered responsible for the facts and opinions advanced in the papers or in the consequent discussions; and it must be understood that such papers may have medals and premiums awarded to them, on account of the science, talent, or industry displayed in the consideration of the subject, and for the good which may be expected to result from the discussion and the inquiry; but that such notice, or award, must not be considered as any expression of opinion, on the part of the institution, of the correctness of any of the views entertained by the authors of the papers."—*Engineer.*

IRON AND STEEL NOTES.

A German paper states that the steel works of Frederick Krupp, of Essen, are about to receive a very important addition to their machinery. The largest steam-hammer at use at these works at the present time is one capable of working a mass of steel 50 tons in weight, and erected at a cost of 2,800,000 francs. It is now in contemplation to build a new steam-hammer capable of beating up a mass of steel of double the weight, viz., 100 tons. The new machine, it is estimated, will cost 5,000,000 francs, and will be the most powerful in the world, and it may be expected that the size and weight of the German artillery will be enormously increased.—*Engineer.*

Purifying Iron.—Mr. Wm. Baker, of Willenhall, employs a vessel or trough placed between the furnace and the moulds or other receiver for the molten metal, and forms the vessel or trough preferably oblong and a few inches deep on one side and shelving up to the top on the other side. He closes the end of the vessel or trough to retain the metal to be acted upon, and forms an opening in the top of each end, one for the admission and the other for the discharge of the molten metals. He forces air through tuyeres placed along that side of the vessel or trough to which the bottom shelves up, and inclines the tuyeres towards the surface of the metal with their nozzles nearly touching the metal, so that the air will be forced into and through the metal. He carries up the sides of the vessel or trough and covers the top with a perforated plate. The metal flows through the vessel or trough and is purified by the action of the injected air.—*Mining Journal.*

Cast Iron Chilled Wheels for Carriages.—A number of gentlemen interested in railways, engineers and others, met at the machine works of Mr. Horn, Millbank Row, Westminster, lately, for the purpose of witnessing the results of tests applied to the "cast iron chilled wheels" manufactured by Barnum, Richardson & Co., of the Salisbury Ironworks, Connecticut. It was stated that these wheels have been in use for a long time both in the United States and Canada on almost all the railways of these countries, with the result that on some lines they are now used to the exclusion of all others. The experience of America, where the frost is so severe, would, therefore, seem to be in favor of these wheels, but as an opinion existed in England that they were easily fractured, the manufacturers resolved to try the question by experiment, and hence the appeal to the tests applied. These were certainly of a severe kind, and it was not until the wheels had been struck 267 times with two hammers weighing 28 lbs. and 32 lbs. respectively, that the iron partially gave way. It is claimed for the wheels that they are not only the most safe, but the most durable and economical—*London Mining Journal.*

Dephosphorization of Iron Ores.—The following process for effecting the dephosphorization of iron ores has been patented by its inventor, M. G. Velge, of Liege:—When a substance containing phosphate of iron is fused with two or three times its weight of a mixture of carbonate of soda and potash, the phosphorus can be removed in the form of alkaline phosphate by washing. Although this process is applicable to the treatment of small quantities only, its principle is that upon which M. Velge bases his own. He found (1) that chloride of sodium can be substituted for these carbonates; (2) that it is sufficient to add to the ore a weight of this reagent only a trifle in excess of the phosphate contained in the substance—say 6 parts of salt to 5 of *phosphate*, or 1 lb. of salt to about 1-5th lb. of *phosphorus*; (3) when the mixture has been well made the ore should not be fused, but kept for some time at a mere red heat. When the gases

have all been given off, water slightly acidulated with hydrochloric acid is added, and the phosphate dissolves after a little time. At first he used to crush the ore and the salt together, but, beside the expense of the operation compared with the low cost of the matter operated on, the final result was unsatisfactory. The ore came out in powder, with which there was every chance of choking the blast. He then proceeded to dry strongly, or slightly calcine, poros ores, adding to them a concentrated solution of sea-salt. This solution was taken up very greedily by the roasted ores, some varieties absorbing as much as 40 per cent. of their weight. In this way all the molecules of phosphorus are brought into the presence of the salt. After calcination and successive washings the quantity of phosphorus held by the ore was reduced from 1.25 per cent. to less than one two-thousandth. Practically, perhaps, so high a degree of perfection would hardly be arrived at, but it it is contended by the inventor that the process itself is quite satisfactory. Four operations are involved in the dephosphorization :

(1.) The desiccation of the ore by waste heat or other suitable method. If there be much phosphorus to remove, it will be best only to use such ores as lose much water on drying. On the other hand, if the ores contain but little phosphorus, it will be useless to dry them.

(2.) The absorption of a solution of salt, stronger or weaker, according to the proportion of phosphorus.

(3.) *Calcining.*—In the ordinary way the gases of the blast-furnace are available for calcining, and when this is the case, the calcining can be effected in a vertical oven, the gases being kindled from below. In the absence of such gases, a reverberatory furnace must be employed, for the calcining in a vertical furnace by admixture of coal has the effect of partly reducing and melting the ore, and thus rendering the washing almost impossible. Not only are the pores of the ore choked in part, but, in the case of silicious ores, the phosphate of soda is converted into silicate of soda. In making use of the blast furnace gases all the carbonic oxyde is consumed before reaching the ore, and there is no sign of reduction, even at the brightest red heat.

(4.) *Washing.*—The ore should be left for several days in vessels filled with water, taking care to renew the water frequently, and to add at each renewal a small quantity of hydrochloric acid. The water by itself would have but a small effect upon the phosphate. It is of the greatest importance to conduct the washing with care, for the success of the operation depends upon it.—*Iron.*

UTILIZATION OF SLAG—ADDRESS BY F. A. LUCKENBACH BEFORE THE SOCIETY OF ENGINEERING.—Frederick A. Luckenbach addressed the New York Society of Practical Engineering at their last session. The speaker's topic was "The Industrial Uses of Blast Furnace Slag," and was illustrated by the exhibition cf specimens. The subject was further discussed by Prof. Whitney, the President of the Society, and by Messrs. Moore, Sutton, Roosevelt, and others. The main points of Mr. Luckenbach's paper are as follows :

Slag is a chemical compound, the combination of an acid with various bases, and is as much a salt as the sulphate of alumina or potassa. Its formation is strictly governed by the laws of chemistry. The silica is the acid, and the lime, alumina, magnesia and the alkalies are the basis. Iron ores are generally silicious. If when an ore is placed in a blast furnace and smelted no base is added, in seeking a base the ore will seize on the oxyde of iron, combine with it and carry it off as slag. To prevent this, limestone, which is a base, is added. A certain quantity of silica requires a certain amount of lime to saturate, another quantity of magnesia, and another of alumina ; all of which quantities will vary with their chemical equivalents. Having then analyses of all the material of the charge, the proportions of each may be so calculated as to produce a certain slag. But with slag, as with other chemical compounds, there may be two atoms of base to one of acid, two of acid to one of base, or one of base to one of acid ; and, according as this is the case, they are called basic, acid, or neutral slags. The acid slags are the most fusible, the neutral next, and the basic the least so. Slag is sometimes, according to the proportions of its component parts, a material easily fusible, and possessed of other definite qualities, and at other times a comparatively infusible material. Such being the character of the product, it has been a problem of great difficulty to determine what general system can be hit upon which for any given purpose will utilize all the different varieties of slag.

The first recorded plan for the utilization of slag was that of John Payne in England, in 1728. He proposed molding the dross by fusing or melting with such mixtures as will prevent its being brittle, and also give it different colors, so as to make it more ornamental and useful. After this came Moshet's plan of 1815, for reworking slag to obtain the iron left in it. Then Crawshay and Moshet invented a process for recovering the iron believed to exist in the refuse of copper smelting, which process appears to be the first use of water for pulverizing molten slag. In 1852, Alexander Cunningham claimed that sulphate of alumina and alum could be obtained from slag. In 1853, William and John Longmand thought blast-furnace slag could be formed into shapes suitable for pavements of streets. In the same year George Robinson proposed a new plan. The slag was to be run in a molten state upon a heated iron table and formed into sheets by rolling. The plates were then to be annealed and applied for roofing and other purposes. In the following year Smith, Bessemer & Longsdon secured a patent on a process in which slag was to be turned into table tops, chimney pieces, statues, etc. Joseph Woodard of Yorkshire, patented a process for making bricks of slag for building purposes. A company of capitalists have lately began to make bricks by this process.

Their prospectus asserts that the brick will withstand a crushing force of over four tons per cubic inch, being five times more than ordinary brick will bear. All these projects have proved failures. The secret of securing homogeneity in structure, irrespective of chemical composition, was not discovered, although the practice of annealing gave a faint and shadowy hint of the direction in which it might be found. Mr. Luckenbach read the details of an invention of his own, which he claimed to be an improvement in the means of annealing castings made of blast furnace slag, and which is designed to provide for the manufacture of paving and building-blocks, fire-brick, and other articles from the slag.

RAILWAY NOTES.

Improvements in Tramways.—The invention of Messrs. Niemann and Geiger, of Vienna, consists in laying the rails of tramways on a number of supports or chairs made by preference of cast metal, and if of metal they are made hollow in the shape of an open box, and bridged over on the top with a recess to receive the rail, so that the upper surface of box and rail is practically level. The box may be filled in with any suitable material. For fixing the rails to the chairs small keys or wedges are driven into grooves formed on one side of the recess, pressing the rail against the other side of recess. To keep the gauge, tie rods may be used.

Fast Railway Travel.—With the improvements made by all the principal American railroads in the last few years, by which a perfection of track has been secured, equal, perhaps, to any in the world, the speed of our express trains is not only rivaling the best time of England, but in some respects surpasses the grandest achievements of travel attained in the mother country. It is no unusual thing for trains in the United States to run at a speed exceeding thirty miles an hour for long continuous distances, and even this rate is considered slow on some of the main lines. As an instance of what can be done by our roads, it is well to state a recent occurrence. Some two weeks ago, a special train passed westward over the Pennsylvania Railroad, carrying an excursion of eastern editors and *literati* on their way to California. The train ran from Harrisburg to Altoona, a distance of 132 miles, in exactly three hours, without stopping. So regular was the speed, and so smooth the track, that scarcely any of the party could realize the fact that they had been traveling through the mountains of Pennsylvania at the rate of forty-four miles an hour, when the time and distance were made known over the dinner table at the foot of the Alleghenies.—*The Railway World.*

A Railroad Three Hundred Feet Above a City.—It is difficult to imagine anything better adapted to produce a vivid and startling impression on the memory than the first sight of Morlaix, Brittainy, as approached by rail. The city lies on both sides a deep, narrow valley and the railroad springs across the chasm on a magnificent viaduct 300 feet high. Entirely unprepared for anything of the sort, the traveler finds himself taking a bird's eye view of a city of the middle ages. There it lies, 300 feet below, almost as if it were in the days when Mary, Queen of Scots, passed through on her way to Holyrood and the scaffold. The precipitous, winding, narrow, darksome streets, the peaked roofs, misshapen by time and studded with curious dormer windows, are still there as when she looked upon them centuries ago, when with brilliant pageant she and her cortege of knights and ladies swept through Morlaix with laughter and song. Should it be a festal day or a fair, the sight is still more unique, for the square is then crowded with booths and peasants in various costumes, and it is positively white with the starched caps of the women. The city is divided by the river of Morlaix, an estuary up which ships come into the heart of the town. The banks of the river are faced with granite, and affords a fine promenade on each side. A smaller stream dashes roaring down the streets, bringing to the dirty lanes of the crowded town the music of the pure fountains whence it came.—*Railway Review.*

The Narrow Gauge in Switzerland.—The first Swiss narrow gauge line, opened in June, 1874, runs from Lausanne (on Lake Geneva), to Echallens, and is of a length of about 9½ miles. The gauge is one metre. This line, which is now being extended to La Sarraz, 7½ miles beyond Echallens, is laid partly into the turnpike road; the maximum gradients are 1 in 25, and the smallest curves have a radius of three chains. The rolling stock, which has been acquired, together with the rails, from the original Mont Cenis mid-rail line, consists of two locomotives, twelve passenger carriages, five luggage vans, and twenty-one goods wagons; the two locomotives however, have since been replaced by tank engines bought at the Creusot works, and there has also been added a small tank engine from Krauss and Co., of Munich. Including rolling stock, the lines has cost but £5,000. per mile. The working speed averages 12 miles an hour, and although the goods traffic is small, the undertaking has proved a very profitable one; this being due, besides the modest amount of capital engaged, to a very simple mode of management.

The Rigi metre-gauge road, a portion of which was already open last season, has been finally opened in June last. The maximun gradients (worked by the adhesion of tank engines of 20 tons weight) are 1 in 20. The rolling stock consists, besides the three tank engines, but of three passenger carriages and of three open goods wagons. The carriages on two four-wheeled bogies have each of them accommodation for 55 passengers, there being eleven parallel transverse benches, each of which is adjacent to a side door. No tourist climbing up the Rigi by either of the two rack railways, should omit a ride on this most interesting "little wonder" of a narrow gauge line, only about four miles in length, but showing along

its serpentine course from Kaltbad to the Scheideck an ever-varying panorama of the most picturesque Alpine world. At the latter station the line reaches an altitude of 1648 metres, or a little over one mile above sea level; this is therefore actually the highest railway in Europe. Like the other Rigi railways, the narrow gauge road is of course only open from May to October, that is to say for about six months in the year.

We next come to the undertaking of the Swiss Society for Narrow Gauge Railways under the direction of President Dr. Dubs. This society, which was founded in September, 1872, by some of the leading Swiss bankers and engineers, obtained in the course of 1873 concessions for the building and working of about 80 miles of metre-gauge railways, situated in different Swiss cantons. But owing to the great and protracted financial crisis of 1874, the society was unfortunately obliged to postpone the execution of the greater portion of these projects, and, in fact, only the metre-gauge railway in the Canton of Appenzel was proceeded with, has a length of sixteen miles, and the class of rolling stock adopted has been fully illustrated and descrrbrd by us (*vide* page 489 of our last volume and page 29 of the present volume). Including everything, this line—established on a very difficult ground—has cost £9,600 per mile; but a line of the normal gauge of 4 ft. 8½ in. would have cost, according to careful estimate, at the least £25,600 per mile.

Among the narrow gauge lines now being executed in Switzerland, the longest will be that from Geneva to Lausanne along the Jura Mountains. Including the lake branches to Nyon and Morges, the length of this line will be 55 miles; the gauge being likewise one metre. This line is being constructed by a local board, who will receive from the Canton of Vaud a subvention of £70,000. There are other narrow gauge projects in the south of Switzerland, regarding which, however, we have at the present moment no precise data; but counting now the lines enumerated above as either opened, building, or concessioned, there will be—at the end of another year—a Swiss narrow gauge *reseau* to a total extent of about 156 miles in operation.

Finally, we have to notice here the narrow gauge tramways projected by the well-known Swiss locomotive engineer, Mr. A. Brunner. These are to be worked by two-storied motive power cars, and a concession has been granted for such a line running from Zurich to some suburbs of that town. In connection with this interesting subject, we must not omit to point out that this progress of narrow gauge railways in Switzerland, as well indeed of their extension throughout the world, is in the largest measure due to the untiring energy of Mr. R. F. Fairlie. It was chiefly by means of his writings, which have been translated into most modern languages, that the advantages of the system he may be said to have inaugurated were thoroughly understood.—*Engineering.*

ENGINEERING STRUCTURES.

THE TUNIS EXPEDITION.—News from the Tunis Expedition has been received to the 15th ult. The Marquis Antinori and Captain Barattieri have visited Gerba Island. The explorers on the southern coast of the Gulf of Gabes sought for the ancient canal connecting Syrtes Minor with Palus Tritonia, but found none. The engineers have returned from the Palustral Basin. They examined the eastern shores. The result of their observations will be published shortly. The heat has caused the wild animals and birds to disappear, but specimens of fossils, stone utensils, and weapons were abundant. The health and spirits of the party were excellent. Colonel Galvagni has collected interesting ethnographical and statistical details.

THE SUEZ CANAL.—The opening of this isthmus was supposed at one time to restore to the Mediterranean ports of France, and especially Marseilles, their old splendor, instead of which most of the steamers prefer to proceed direct through the Straits of Gibraltar, thus leaving the French railways to their own greediness. Nor has the French merchant navy been in due proportion benefited by the opening of the new sea-road to the far East. The French Shipping passing through the canal decreases, relatively speaking, from year to year. In 1870, 436,000 tons burthen passed through the canal, of which 289,000 were English, and one-fifth, or 84,000 only, French. In 1874, the proportion of French bottoms is found to be reduced to 220,-000 tons, or less than one-tenth, 2,423,000 tons having passed the canal, out of which 1,797,-000 were under the English flag. The other navies, although below the absolute figure for France, are progressing more rapidly. Thus, since 1872, four times more Dutch ships used the canal, while the increase of the French navigation was only 40 per cent.

THE MISSISSIPPI IMPROVEMENTS.—The Board of Engineers, which assembled for the purpose of considering the plans of Captain Eads for the improvement of the Mississippi, have concluded their labors for the present.

The following gentlemen constituted the Board at its recent session: Gen. Barnard, President; Sir Chas. A. Hartley, Gen. Alexander, Messrs. Roberts, Whitcomb, and Sickles. After considerable discussion, the Board agreed unanimously upon the following report:

I. With regard to the priority of construction of different parts of the work, the Board recommended that the seats of both jetties and of the spar joining the west jetty with the right bank be protected with mattresses throughout this entire length—that is, that first of all the foundation of the east jetty be secured out to a depth of 30 feet, and of the west jetty to 20 feet. They further recommend that the east jetty be carried up the water line before raising the mattress wall of the west jetty to the same level, and that the construction details of the pier-heads be left

till the Commission can meet at the jetties this Fall.

II. After attentive examination of the plan of construction, consisting of a combination of willow mattresses and stone, now in execution by Mr. Eads, the Board find it to be a modification of methods long in use in Holland and elsewhere. It is essentially the same as that applied to the jetties of the mouth of the Oder, and also to the jetties at the new mouth of the Maas, so satisfactorily as to draw from the legislative body of Holland the expression that "their complete success has removed all doubts as to the possibility of making piers at sea on our coast." It is moreover essentially the same as that adopted by the recent Commission (1874) for these works.

III. The Board advise that Bayou Grande be left open for the present.

The same Commission will reassemble at the mouth of the Mississippi during the latter part of October or the first days of November.

The St. Gothard Tunnel.—The international Commissioners, whose duty it is to inspect and report upon the progress made with the St. Gothard Tunnel and railway, have this year required a more detailed statement of the work executed than has been hitherto furnished. This statement appears in a tabular form accompanied with explanations and remarks in the *Politecnico*, a scientific journal published at Milan. From it we learn that during the last three months before the publication of the report there had been excavated at the Goenechen or Swiss side of the mountain 341.3 metres, being at the rate of 3.71 metres per day, and on the Italian side at Acrolo, 184 metres, or at the rate of only 2 metres per day, which together would give a progress at the rate of 2,100 metres per annum, the comparatively slow progress made on the Italian side being due to the hard nature of the rock met with, through which fortunately, however, little water percolated, so that the work was not impeded by that hitherto prevailing obstacle. With reference to the masonry and the excavation of the tunnel to its full dimensions—these are (says the report) evidently proceeding so slowly that series embarrassment is likely to result from having too great a length of the small tunnel or drift way excavated in advance of the completed work. The number of perforators in operation, worked by compressed air, are stated to be sixteen in number, the compression of the air being effected by water power. We are left uninformed as to the length of the tunnel actually completed, as opposite the heading in the tabular statement "Length of Tunnel Completed," no figures appear. As regards that portion of the St. Gothard railway which follows the valley of the river Ticino, the works appear to have been prosecuted with considerable energy, as trains have been running on the sections Lugano-Chiasso and Biasco and Biasco-Bellinzona ever since December 6 last, or exactly three years since the formation of the St. Gothard Railway Company. As regards the section Bellinzona-Locarno, it has not been opened in consequence of the damage done by floods, which had rendered it impossible to construct the iron bridge at Verzasca. There are still incomplete in two other sections of the line many complementary works, and in some instances the trains have to pass through tunnels in which the centres and supports still remain. These lines have been opened rather in compliance with a stringent clause in the concession than that they can be considered in a fit state for traffic.

ORDNANCE AND NAVAL.

Field Artillery Experiments at Dartmoor.—The series of trials of the effect of the fire of our service horse artillery and field artillery on broken ground representing the conditions of actual warfare, is now in progress. The principal objects are the trial of the relative effects of shrapnel shell with time and percussion fuzes, of common shell burst with powder, and also with gun cotton with the surrounding space filled with water, and the cotton fired by a detonator; the efficiency of Capt. Nolan's range finder, as compared with the employment of individual judgment and trial shots to ascertain the distance of an enemy. It is proposed to review the result of these experiments when the series is completed.—*Engineer*

The Deutschland.—This iron-armored frigate, the sister ship to the Kaiser, built for the Imperial German Government by Messrs. Samuda Brothers, from the design of Mr. E. J. Reed, is now almost ready to be handed over. She is at present in the Millwall Docks. It is said that there is no dry dock on the Thames large enough to hold her. Though her length is only 280ft., her beam is 63ft.; still we should have thought that she could have been accommodated either in Messrs. Lewis and Stockerill's dry dock, or at the Thames Ironworks. Perhaps, however the German Government like to save a few pounds as much as any one else. The magnificent work put into her both by Messrs. Samuda and by Messrs. Penn, who have supplied the engines, deserves the highest commendation. Indeed, the engines are a picture to feast the eye upon—their compactness and finish being so admirable. We notice that in these two frigates Messrs. Penn have introduced some improvements which are not to be found in any of their previous engines. Formerly the screw-shaft worked upon only three bearings, with the turning-wheel at the after end of the engine room, situated about the middle of a length of shaft between two bearings some 11ft. apart, by which great vibration was caused. Now a fourth bearing has been introduced, and the turning-wheel placed in the centre of the engine-room, by which means great steadiness ensues. This arrangement also admits of the shaft being made in two pieces, and coupled in the centre. The Kaiser and Deutschland are also provided with steam starting-gear, which we do not remember having seen before fitted by Messrs. Penn to trunk-engines. The Deutschland is complete with the exception of her guns, of which she

is to carry eight 26in. guns of 22 tons each, and one 22in. gun of 18 tons. These are to be supplied in Germany, by Messrs. Krupp, of Essen, who will also fit the racers for them. —*Engineer*.

BOOK NOTICES.

How to Teach Chemistry. By Edward Frankland, F. R. S. London: J. & A. Churchill. For sale by D. Van Nostrand. Price $1.25.

This is simply a condensed report of six lectures delivered by Dr. Frankland, and carefully summarized by one of the science teachers at South Kensington.

The suggestions afforded to teachers are of the highest value, not only as to the order of subjects, but in reference to the manipulation of apparatus in illustrating the science.

The diagrams are numerous and excellent.

Notes on Certain Explosive Agents. By Walter N. Hill, S. B. Boston: John Allyn. For sale by D. Van Nostrand. Price $1.00.

This work is in the form of a pamphlet of seventy pages; but within this space is included an epitome of the present knowledge of all the explosive agents at present in use.

The topics treated in separate chapters are: I. Explosions and Explosive Bodies; II. Nitro-Glycerine; III. Gun Cotton; IV. Picrates and Fulminates; V. Classes of Explosive Mixtures; VI. Use of Nitro-Glycerine and Gun Cotton.

Some folding plates illustrated the manufacture of Nitro-Glycerine.

A Dictionary of Chemistry. By Henry Watts, B. A., F. R. S. London: Longmans, Green & Co. Second Supplement. For sale by D. Van Nostrand. Price $15.00.

The Second Supplement to this well known work completes the record of chemical discovery down to 1873, and contains the more important advances in science made in 1874.

The volume is quite as large as either of the others.

The leading contributors, with the list of their contributions, are given herewith:

H. E. Armstrong, F. C. S.—Phenols—Sulphur Chlorides.

G. C. Foster, B. A., F. R. S.—Magnetism.

H. E. Roscoe, F. R. S.—Chemical Action of Light, Spectral Analyses.

Robert Warrington, Esq., F. C. S.—Fodder, Maize, Malt, Oats, Root Crops.

The Mechanic's Friend; A Collection of Receipts and Practical Suggestions. With numerous Diagrams and Woodcuts. Edited by Wm. E. A. Axon, F. S. S. New York: D. Van Nostrand. Price $1.50.

This convenient little volume is made up of those applications of Physics and Chemistry, with which amateurs chiefly delight to deal.

Most of the matter has appeared in the columns of the *English Mechanic* during the past two or three years, such selections having been made from those columns as seemed most valued by the readers.

Upon such subjects as the following there are several articles by as many differe n inal writers: Bronzing, Cements, Dyes, Electricity, Gilding, Glass Working, Glues, Horology, Lacquers, Locomotives, Magnetism, Metal Working, Photography, Pyrotechny, Solders, Steam Engines, Telegraphy, Taxidermy, Varnishes and Water Proofing.

Perhaps the more interesting portions of the book to the mechanic will be those relating to Tools, Locks, and Special Processes in Mechanical Engineering and Chemistry.

The illustrations are all good.

Rudiments of Geology. By Samuel Sharp, F. S. A, F. G. S. London: E. Stanford, 1875. Price $1.75.

The introductory portion of this little book was originally prepared for use in the writer's class, and is now published, with large additions, for the benefit of persons similarly circumstanced, and of private students. Neither could desire a more useful help, for we know of no book in which the principles and facts of geology are so well epitomized, or in which either are stated in such a clear and popular manner. The introductory part deals with the generalities of the subject, its divisions, the materials of the earth's crust, and the manner in which these have been formed and modified, all of which is presented in such order as to be both easily comprehended and remembered by the learner. The second part is stratigraphical and paleontological, and in it the different formations are described in ascending order, and their construction and characteristic fossils indicated. Much that is important in the philosophy of the science is also communicated in this division, and the work as a whole may be honestly recommended to educators and self-educators alike as a cheap and reliable handbook.

Hydrology of South Africa; or Details of the Former Hydrographic Condition of the Cape of Good Hope, and of Causes of its Present Aridity. Compiled by John Croumbie Brown, LL. D. Kirkcaldy: J. Crawford.

The above title explains fully the scope of the work. It is a valuable contribution to the science of Physical Geography. The practical bearings of the subject are not at first apparent, but are none the less real. The decrease or increase of rainfall in different sections of our country is a subject upon which we have no definite knowledge. Such changes are so slow that much time is required to gather data enough to establish the fact of any permanent change. In the case of South Africa, the writer finds that a close study of its topography yields much information of value.

The contents, as given by chapters, are as follows: Testimony supplied by the Physical Geography of South Africa; Testimony in regard to former condition of South Africa supplied by Geology; Indications of former Hydrographic Conditions; Hydrographic Condition within the Historic Period; Primary Cause of Desiccation of South Africa; Secondary Causes; Aridity and Water Supply beyond the Colonized portions of the Country; Water Supply within the Colony.

The writer has availed himself of the testimony of standard authorities, and extracts from former writings are quite abundant. There are no maps nor illustrations of any kind.

PRACTICAL GEOMETRY AND ENGINEERING DRAWING. By G. SYDENHAM CLARKE, R. E. London, 1875.

Lieut. Clarke is instructor in geometrical drawing at Cooper's Hill College, and a few words from his preface will best explain the origin as well as the plan of his book. In dealing with large numbers of students, the writer felt the want of "a text-book which explained first principles fully and systematically, which preserved a clear and logical sequence throughout its pages, and which furnished examples bearing directly on the subject-matter of each chapter. Existing works did not satisfactorily meet the case. Some supposed the student to know too much, others gave him credit for knowing nothing. . . . . . The objects of the writer have been to bring general principles into prominence, to illustrate those principles by a variety of problems fully explained, pointing out at the same time any peculiarities worthy of remark; and finally, to append to each chapter a number of problems with occasional hints as to their solution." The plan thus sketched out is systematically adhered to, each chapter in the section on solid geometry starting from principles and definitions, going through explanations in detail, and concluding with examples. Two chapters on the methods of execution of engineering drawings, and the selection and use of drawing instruments, furnish the student with common sense practical hints on subjects which, though secondary, are not unimportant in regard to rendering drawings clear, neat and intelligible.—*Builder.*

THE MECHANIC'S GUIDE: A PRACTICAL HAND BOOK FOR THE USE OF ENGINEERS, MECHANICS, ARTISANS, &C. By W. V. SHELTON. Charles Griffin & Co. Price $3.75.

The compiler of this treatise, who is foreman of the Imperial Ottoman gun factories at Constantinople, states as his object "the gathering into one connected *whole* the principal subjects relating to various branches of the mechanical art, and placing before readers who may not have much leisure for study a concise and simple explanation of general principles, together with illustrations of their adaptation to practical purposes. . . . . The book is the work of a practical mechanic, who may not have the language of a professor at command, but who has tried, to the best of his ability, to supply, honestly and thoroughly, information such as he knows to be greatly needed by intelligent mechanics of the present day." The book is, in fact, intended to be to the working mechanic what Molesworth's and other pocket books are to the engineer and architect. It is a book of reference giving arithmetical formulæ and practical instructions for the carrying out of a great many problems in mechanical work, especially in regard to the setting out and proportioning of parts of machinery. Numerous tables, of the weights and specific gravities of materials, the circumference and areas of circles, &c., are added in an appendix; and the volume appears to be the result of considerable thought and care, as well as practical experience. Short treatises on arithmetic, practical geometry, and mensuration, precede the experimental chapters.

MISCELLANEOUS.

PLUMMET LAMP FOR SURVEYING IN MINES.—An ingenious lamp for the use of mine surveyors has been designed by Mr. Heller (of Heller and Brightly), of Philadelphia, and was described in a paper read before the American Institute of Mining Engineers at the St. Louis meeting. The improved lamp can be used either with or without the safety apparatus, according as fire-damp may or may not be present. The safety apparatus resembles to a certain extent that of the Musseler lamp. It consists of a ring and plate united by four rods. The plate has a cylindrical hole in the middle, and four apertures distributed radially around it. In the centre cylindrical hole is fitted a conical brass chimney, which projects below the plate and is fastened thereto, being kept vertical by four wire braces, or stays, which are soldered to the top of the chimney, and to the outer edge of the plate. The top of the chimney terminates in an in inverted frustum of a cone which is made hollow, and is drilled full of small holes. The inside is lined with one thickness of wire gauze. On the upper part of the cone is screwed a brass cap, composed mainly of a brass ring and wire gauze; the smoke, &c., pass out through the latter. This cap must be cleaned from time to time, depending upon how much the lamp is used, and how much it smokes. It is as well to carry an extra cap in the pocket, which can be put on when the dirty one is taken off. An easy way to clean the cap is to allow a jet of steam to blow through it. The four radial apertures in the plate are also covered by two thicknesses of wire-gauze. Between the top of the plumb bob and the bottom of the plate, and inside of the four vertical wires, is inserted a cylinder of glass. When the safety apparatus is to be used the compensating ring is removed from the ring and placed upon the plate, which has two conical holes corresponding to those in the ring; the ring is unscrewed from the top of the plumb-bob, and another ring is screwed on in its place with the glass cylinder on top of the plum-bob. As the second ring is screwed up the glass cylinder is clamped between the plumb-bob and the plate, making nearly an air-tight joint; the lamp having been lighted before the safety apparatus was screwed on, is now ready for use. The air passes down through the four radical orifices in the plate, which are covered with two thicknesses of wire gauze, is heated by the flame and rises through the chimney passing out through the wire gauze top. The glass is quite thick and well annealed. He has allowed the lamp to burn nearly an hour, until the glass was quite hot, and then thrown cold water upon it without producing any effect whatever on the glass. The wick should not be high, as a very short

one gives light enough and not much smoke. The best kerosene (of as high a test as possible) should be used in the lamp, as the latter gets warm. The top of the wire gauze covering of the chimney becomes more or less clogged with lamp-black, which can be removed from time to time with a fine brush.

DIAMOND ROCK BORING.—A party of gentlemen connected with mining, amongst whom were Messrs. H. Cain, C. E. Bainbridge, J. Walton, T. D. Bolton, T. Rummey, V. Hodgson, F. H. Edwards, T. Kell, and others, met at the Hope Level, Stanhope, on Saturday last, to witness the work which is now being carried on by the Diamond Rock-Boring Company, under the superintendence of their agent, Mr. C. Adkin. Major Beaumont, M. P., the managing director of the company, and inventor of the system, was present, and fully explained the working of the machinery, which consists of a motor, similar in construction to a horizontal steam engine, worked by compressed air, the exhaust serving to ventilate the tunnel. The machine itself consists of a bed-plate, on which are fitted two standards; on these are fitted movable saddles for carrying the drills, which can be worked at any angle and in any position, power to drive these being given from the motor by means of a diagonal shaft, driving bevel gearing. The drills consist of a brass quill and nut, mounted in a cast-iron frame, through which passes a hollow screwed drill bar, on the one end of which is fixed the crown, or boring tool, which is simply a small steel tube, set at the end with pieces of carbonate (diamonds in an uncrystallized state.) On the other end is screwed a water union, fixed to a flexible pipe, through which is forced a supply of water when drilling which not only tends to keep the crown cool, but also removes the debris resulting from the borings from the holes. On the nut is placed a firiction clutch, so arranged by means of a screw that should the drill come on strata of such a nature that it cannot be bored at the maximum speed, the friction nut slips, and only allows the nut to feed forward the drill bar at the actual speed at which the rock is bored, which was, as we saw on Saturday, in hard limestone at the rate of 4 in. per minute.

The method of working is as follows :—The machine, which is on wheels running on rails laid on the floor of the tunnel, is run to the face; the standards are then tilted forward into position by means of power supplied from the motor, and firmly fixed to the roof by means of screw-jacks at the top of the standards. A set of holes are then put in at various angles and in different positions in the face of the rock from 4 to 5 ft. deep, when the standards are tilted back, and the machine run back to a safe distance, when the holes are blasted, and the debris removed.

The work at Hope Level was, previous to being taken up by the Diamond Rock-Boring Company, being driven by hand labor at a speed of from 1 to 1½ yard per week, while now the rate of progress is from 10 to 12 yards, thus clearly showing that a speed of eight times that of hand-labor can be obtained by the use of this machinery, which where the mineral resources of a place is required to be fully and speedily developed would be a decided advantage, and we doubt if similar results than those above given can be obtained by any other machinery; and in a district like Weardale, where so much mineral is yet undeveloped, we are surprised that the Diamond rock-boring machinery has not been more generally adopted.—*Mining Journal.*

BRICKS AND BRICK-DRYING.—We have received some particulars of a brick-making process at works set up by Mr. Stephens at Kidwelly. Upon entering the works the first thing to be seen is a stone-crushing machine, into which the stones are cast and crushed to pebble size; from thence they are shoveled into a pan, over which two large rollers are worked, which grind the stone to powder. Both the pan and rollers are lined with chilled iron, and so are proof to damage by the hard silica stones from Mynydd-y-garreg. While the grinding process goes on a small white stream of a liquid compound falls into the pan which brings the powdered stone into the substance of mortar; then it is delivered to the moulder, who deposits the composition into a double-mould, places it into a press, which answers the purpose of pressing closely the bricks and of forcing them out of the mould. Then a lad carries them on a sheet of iron and places them in the oven for drying under the new process. This oven is constructed very much on the same principle as a baker's oven, only considerably larger, but in lieu of one floor their are several tiers constructed of upright and horizontal irons about 5in. apart, upon which to lay the bricks, so that the oven can be filled from bottom to top, capable of storing about 10,000. When the oven is full, the iron doors are closed up air tight. Certain flues admit the hot air, and the bricks are said to be thoroughly dried in from three to four hours. Under the old process it would take twelve hours, with the consumption of two tons of coal and the labor of several persons over a large area of ground to dry 5,000 bricks; under the new system 10,000 bricks can be dried in three or four hours with 2 cwt. of coal, with less than half the manual labor, and without the extreme exhaustion caused to the workmen from being hours in the old dry-houses. The originator of the idea is Mr. P. Conniff, an experienced man in the trade.

REFRACTORY CLAYS.—The study of the refractory properties of a clay of given composition is one most important to metallurgical operations. Dr. Carl Bischof has for some time been devoting his attention to the investigation of this subject, with the double object of estimating the refractory properties of a clay of any given composition, and also their respective behavior in the presence of liquefied metal. He has found a wonderful relation almost constant between the chemical composition and the properties of any clay provided that the physical conditions are in all cases the same. The refractory power of clays is determined by the quantity of pure pulverized quartz with which it is necessary

to mix them in order that they should present any considerable resistance at high temperature. Instead of the quartz, a mixture of equal parts of silica and alumina may be used with advantage, in order to obtain even greater precision still in the results. The proportion of this mixture added should be rather greater than that of the quartz. The refractory properties of the clays are represented by reference to a standard clay whose refractory power is taken at 100. This typical fireclay, when a portion of the mixed silica and alumina has been added, and been exposed to a heat sufficient to melt iron, breaks with an earthy fracture, and seizes the tongue when applied, and absorbs an ink-mark traced by a pen on its fracture. This should be the characteristics of all the good refractory clays. To find the respective co-efficients in each case, multiply the reduction or increase in the quantity of mixed silica and alumina added (taking the amount of the typical clay as 1) by 10 and subtract the product from 100, the remainder will give the respective refractory co-efficients of the different clays, that of the type being 100.

The action of liquid cast-iron on the clays has been estimated by mixing four parts of iron with 100 parts of the clay investigated. At the melting heat of wrought iron, the influence of the oxyde of iron has been found nil; the lime, however, and the potassium have produced a vitreous surface. The manganese produces a similar effect, taking place intermediately with the lime and potassium. The chemical analysis and the experiments have clearly shown that the proportions between the alumina and silica, or between the alumina and the cast-iron, vary in the same proportion as the co-efficients of resistance. This rule was subject to a few exceptions, but it was proved that these exceptions were owing to the physical condition of the clay. It is then but necessary to pay attention to dryness or dampness of the clay to obtain accurate pre-knowledge of results from the chemical composition of the clays.

The above general principles will also apply equally as well to the case of clays subject to the action of glass, of slags, of metals, of metallic oxydes, of bases, and of salts, of cinders, &c. There is a perfectly definite composition to be produced in the typical clay to give the best possible refractory and resisting powers. Here, again, the action of the metal, &c., on the clay is found to be less strong as the co-efficient of the refractory power rises.

Roux and Sarrau have previously shown that two different kinds of explosions can be produced by dynamite, according as the substance is made simply to deflagrate (explosion of the second order), or to detonate by the percussion of fulminate of mercury (explosion of the first order), and that the force of the explosion produced by the same quantity is very different in the two cases. They now find that the majority of explosive substances, gunpowder included, possess the same remarkable property. The reciprocal of the weight (due corrections made) of each substance, which when exploded in one and the other manner sufficed to rend similar cast-iron shells, gave the relative explosive forces. Some results of the experiments are given in the following table, the explosive force of gunpowder igniting in the ordinary manner being taken for unity:

Name of substance.	Explosive force. 2d Order.	Explosive force. 1st Order.
Mercury fulminate	—	9.28
Gunpowder	1.00	4.34
Nitroglycerine	4.80	10.13
Poroxyl (gun cotton)	3.00	6.46
Picric acid	2.04	5.50
Potassium picrate	1.82	5.31
Barium picrate	1.71	5.50
Strontium picrate	1.35	4.51
Lead picrate	1.55	5.94

Of the hignest practical importance is the discovery of the detonative explosion of gunpowder induced by the detonation of nitroglycerine—itself set off by the fulminate of mercury—for the force of the explosion is more than four-fold greater than that obtained by igniting gunpowder in the ordinary manner. The increased force of gunpowder and gun cotton, when exploded by the agency of detonation, was fully demonstrated by Abel six years ago. The authors observe that the mass of the substance employed for exciting detonation must usually bear a certain proportion to that of the substance to be exploded, but in some cases the action is propagated throughout the latter when once up at any given point.—*Engineering.*

Electric Resistance of Various Metals.—M. Benoit has measured with great precision the electrical resistance of various metals at temperatures from 0° to 860°. He employed both the method of the differential galvanometer and of the Wheatstone's bridge, and for each method has measured several specimens. The mean of these is given in the following table, the second column giving the resistance of a wire, 39.37 inches long and having a cross section of 0.03 inches in ohms, and column three the same quantity in Siemens' units. Column four gives the resistance compared with silver:

Metal.	Ohms.	Siemens.	
Silver, A	.0154	.0161	100
Copper, A	.0171	.0179	90
Silver, A (1)	.0193	.0201	80
Gold, A	.0217	.0227	71
Aluminum, A	.0309	.0324	49.7
Magnesium, H	.0423	.0443	36.4
Zinc, A., at 350°	.0565	.0591	27.5
Zinc, H	.0594	.0621	25.9
Cadmium, H	.0685	.0716	22.5
Brass, A (2)	·0691	.0723	22.3
Steel, A	.1099	.1149	14
Tin	.1161	.1214	13.3
Aluminum bronze, A (3)	.1189	.1243	13
Iron, A	.1216	.1272	12.7
Palladium, A	.1384	.1447	11.1
Platinum, A	.1575	.1647	9.77
Thallium	.1831	.1914	8.41
Lead	.1985	.2075	77.60
German Silver, A (4)	.2654	.2775	5.30
Mercury	.9564	1.0000	1.61

A, annealed; H, hardened; (1) silver .75; (2) copper 64.2, zinc 33.1, lead 0.4, tin, 0.4; (3) copper 90, alluminum 10; (4) copper 50, nickel 25, zinc 25.

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BRIDGE AND TUNNEL CENTRES.

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I.

In the construction of stone and brick arches, of whatever shape and span, and to whatever use applied, whether as supports for roadways or roofs of tunnels, there is nothing which requires more careful attention on the part of the constructing engineer, than the centres. Independent of the choice of material, of the exactness with which each stone is cut, and the care with which it is laid in place, the success of arches of great span, their settlement and ultimate stability depends essentially on the care given to the framing, setting up and striking of the centres. The slightest change in the shape of the frame caused by the shrinking of an ill-seasoned timber, or the yielding to compression of a badly proportioned brace, will assuredly be followed by a change in the curve of the intrados, which may possibly result in the ruin of the arch itself.

Well constructed centring, therefore, is indispensably necessary to a well constructed arch, and in the following papers it is our intention to offer a practical investigation of the principles which must be followed out in the planning and mechanical execution of all such centre frames; to determine what strains must be withstood, at what point they act with most vigor, and by what combination of beams and by what system of bracing, the greatest strength and stiffness may be combined with the utmost lightness and the strictest economy of material.

BRIDGE CENTRES.

Of all classes of centres, the most complicated in structure is, beyond doubt, that of a large span stone bridge. Like a roof frame, it consists of a number of vertical pieces, placed in the direction of the span, from 5 to 7 ft. from centre to centre, and known as the *ribs*, upon which are placed horizontal pieces or *laggings*, and on these latter rest the voussoirs till the key stone course is driven and the arch becomes self-supporting.

The frame in its turn is composed of *back pieces*, or short beams cut on the outer edge to the same curve as the intrados of the arch, a horizontal *tie beam*, and a number of *struts*, *ties* and *braces*, the arrangement, number and dimensions of which, will depend on the shape and span of the arch, and the number and position of the points of support. Whatever may be the span and curve of the arch, and the points of support afforded, experience has amply proved that the ribs should be polygonal in shape, with short sides; this shape being given by forming the

back-pieces, on which rest the laggings, of two or more courses of planks, placed in the form of a polygon and firmly nailed together; the planks in each course abutting end to end by a joint in the direction of the radius of curvature of the arch, and breaking joints with those of the other course.

For light arches of moderate span, or indeed for heavy arches of wide span when firm intermediate points of support can be had between the abutments, the back pieces may be strengthened by struts or ties placed under them, well braced, and abutting against a horizontal tie beam. This beam spans the arch a little above the springing line, is bolted to the back-pieces at either side, thus preventing them from spreading laterally, and if well sustained by props from beneath, affords a firm support to the struts and braces of the rib. In by far the greater number of cases, however, where headway is required under the centring during the construction of the arch, as is the case with stone bridges spanning a river whose navigation cannot be impeded, or whose current is too swift and depth too great to give firm points of support to the props of the tie beam, it becomes necessary to do away with the latter, and supply its place by such an arrangement of beams as will transmit the strains received to points of support at the abutments. This latter class of centring is known as "*retroussée*" or "*cocket*," and requires a much more careful and elaborate arrangement of its parts than the former.

We have therefore two classes of bridge centres to deal with; one in which the frame is constructed without regard to headway beneath it, and is supported from firm points of support between the abutments, and one arranged to leave headway under the frame, and upheld by framed supports at the abutments.

Before attempting to determine the most advantageous arrangement of the pieces which must compose the frame, their number and the dimensions it is necessary to give them in order that they may offer a solid support to the arch stones, it is fitting to consider the effect of the load the ribs are expected to uphold, the strains it produces, the points where and the directions in which the strains act and their intensity.

THE STRAINS.

The strains to which centre frames are subjected arise solely from the pressure upon the back-pieces and laggings, due to the weight of the voussoirs laid upon them, and are therefore extremely variable, depending on the span and curve of the arch, and the thickness and weight per cubic foot of the voussoirs which press upon the centring. It is not, however, to be supposed that *all* the voussoirs from springing line to springing line *do* press upon the frames, this depending to a very great degree on the curve of the arch. If, for example, we take the case of a full centre arch and starting at the springing line on either side pass towards the crown, we shall find that for a considerable distance above the springing line the stones do not exert any pressure upon the ribs, but that, as soon as this point is passed, the pressure begins and increases rapidly, reaching its maximum intensity just before the keystone course is driven into place. When this is done the pressure is almost entirely removed, and were it not for the slowness of the mortar in drying, the frame work of the arch might be done away with.

And, here, I would mention that, although it is generally held that when the keying course is placed, the voussoirs, with the exception of a few courses at the crown, cease to press, I have found by the most careful experiments with large, well-framed models, that the thinnest Chinese paper when coated with black lead and placed under the blocks of arch stone, *could not* be *drawn out*, even when the arch was keyed, without considerable resistance.

Upon further examination it will be found that these voussoirs which lie near the springing line and exert no pressure upon the laggings and back-pieces, are all of them contained within the angle of repose; that is to say, the voussoirs do not begin to press upon the centring until we reach one whose lower joint makes so great an angle with the horizon, that the stone is caused to slide along its bed under the action of gravitation. This angle for full centre arches has been fixed at from 28° to 30°, but

the quality of the stone and mortar used, will cause it to vary greatly. For ordinary cut stone, we may with safety assume the angle of friction at 30° with the horizon: when laid in thin tempered mortar it is increased to 34° or 36°, and with very porous stone, such as freestone, laid in full mortar it will reach almost 45°.

It is to be observed, however, that this is not strictly true unless the arch is of sufficient thickness at bottom to prevent all tendency to upset inwards. A thickness of $\frac{1}{10}$ the radius of curvature is usually adopted as sufficient for this purpose.

Adopting 30° as the angle of repose for cut stone, the number of voussoirs which load the centre will depend on the curve given to the intrados. If we take, for instance, a full centre, an oval and a flat segmental arch, and give to each the same number of voussoirs, it is evident that the number of stones which do *not* press on the laggings will be greatest in the full centre, less in the oval, and least of all in the flat segmental arch, because in this latter case the stone whose lower joint makes an angle of 30° with the horizon will be found nearer the springing line. We should expect, therefore, the number and weight of the stones being the same, that the segmental arch could give the greatest load to the centres, and the full centre arch the least; and this is strictly the case.

In estimating the load upon the centres in any case, it is to be remembered that none of the stones bear upon the ribs with their entire weight, a part of this latter being consumed in overcoming friction. The determination of the amount of weight thus expended is a matter of some mathematical intricacy, and we are indebted for its solution to M. Couplet.* By his calculation he found that the total weight of the voussoirs which *do* press on the laggings, is to the weight with which they actually load the frame, as an arc of 60° is to twice its sine less the same angle; or, to express it algebraically, denote by P the total weight of the voussoirs which *rest* on the centring, and by p, the weight with which they *load* the centres, and we shall have the expression

$$P : p :: \text{arc } 60^\circ : 2\sin 60^\circ - \text{arc } 60^\circ \qquad (1)$$

or

$$p = \frac{P\,(2\sin 60^\circ - \text{arc } 60^\circ)}{\text{Arc } 60.} \qquad (2)$$

If, therefore, we suppose the radius of a circle to be divided into 10,000 equal parts, the circumference will contain 62,832, and the arc of 60° 10,472, and its sine is equal to $\frac{1}{2}\sqrt{3}$,8660. Substituting these values in the above equation (1), we shall have

$$P : p :: 10472 :: 2\times 8660 - 10472 \quad \text{or}$$
$$P : p :: 10472 : 6848$$

which gives us a ratio of 3 to 2 very nearly. Whence we see that the voussoirs in a full centre arch which press upon the laggings will do so with but $\frac{2}{3}$ of their weight, and, taking the angle of repose on each side at 30°, only on $\frac{2}{3}$ of the surface of the centring. We may, therefore, without any sensible error take $\frac{4}{9}$ of the gross weight of the voussoirs of the arch to express the load on the centres.

With an arch which is not full centre the case is quite similar. We will take an oval of three centres fulfilling the conditions that each of the three arcs composing it shall be 60°. This oval being drawn, it is at once apparent that the arcs of 60° at each end of the oval do not differ materially from that of 30° in the full centre arch. We may, therefore, to facilitate calculation, safely assume that the stones forming these two arcs of 60° do not press on the centres, when the arch is all up except the keystone, and are held in place by the weight of the voussoirs above them. There remains then but the central arc of 60° to load the framing. But from equation (1) P : p as the arc of 60° is to twice its chord less the arc of 60°; and since 60° is to its chord very nearly as 22 to 21, we may without sensible error express the relation of P to p by the ratio of 11 to 10. When we have found the gross weight of the voussoirs in this arc of 60° it follows that we must take $\frac{10}{11}$ of their weight to express the load on the framing.

The chord of an arc of 60° is equal to

* Mémoire de l'Academie Année, 1792.

the radius, and the radius in this case being 10000, the *chord* will equal 10000, and the *arc* of 60°, 10472. Hence we have the relation 10000 : 10472 :: 21 : 22 *nearly.*

These values may also be obtained from the integral calculus, in which case no regard is taken of friction, and the formulæ are therefore a little uncertain. This uncertainty, however, is on the side of safety, for when we leave out of consideration the pressure expended in overcoming friction we are forced to give the ribs and laggings unnecessary strength.

Referring to Figure 1, we wish to find the load which the voussoirs between A B C D give to the centre's rib.

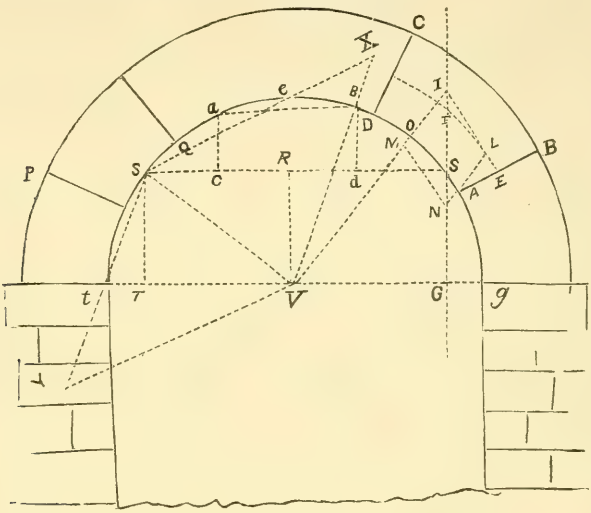


FIG. 1.

Let w equal the weight per lineal foot of intrados of the arch resting on the rib.

By x and y the horizontal and vertical co-ordinates respectively of the point A.

By x' and y' the co-ordinates of D.

By r the radius of the curve of intrados at A, and

By α the angle it makes with the horizon.

By P the gross vertical pressure on the rib of A B C D.

By p the pressure per lineal foot of intrados at A.

Then we shall have

$$\mathrm{P}=\int_{x'}^{x} p\,dx \quad . \quad . \quad . \quad (3)$$

From this we may compute the load on any vertical post at this point, or the vertical component of the load on the back pieces.

If the arch had been completed up to the keystone course, equation (3) would have been

$$\mathrm{P}'=\int_{0}^{x''} p\,dx \quad . \quad . \quad . \quad (4)$$

P′ being the greatest vertical load on the *half* rib, and x'' the horizontal distance from the middle of the span to a point where p is zero.

The value of p is found from the equation

$$p=\mathrm{W.}\cos\alpha-\frac{1}{r}\int_{y}^{y'} \mathrm{W.}\,dy \quad . \quad (5)$$

which will evidently be greatest when

$$p=\mathrm{W.}\cos\alpha \quad . \quad . \quad . \quad . \quad (6)$$

When the arc is a segment of a circle not greater than 120°, we shall have from the relation between the sides and angles of a triangle, the following values of the co-ordinates :

$$x=r\sin\alpha \qquad x'=r\sin\alpha' \quad x''=r(\sin\alpha'')$$
$$y=r\,(1-\cos\alpha\,) \qquad y'=r\,(1-\cos\alpha')$$

Substituting these values in equation (5) we shall have

$$p=w\,(2\cos\alpha-\cos\alpha'). \quad . \quad . \quad (7)$$

And from the expression $y = r(1-\cos\alpha)$ we have

$$\cos\alpha = \frac{r-y}{r};$$

and from $y' = r(1-\cos\alpha')$

$$\cos\alpha' = \frac{r-y'}{r}$$

Substituting this in equation (7) we shall have

$$p = w\left(\frac{2r-2y}{r} - \frac{r-y'}{r}\right)$$

$$= w\frac{r-2y+y'}{r} \quad . \quad . \quad . \quad . \quad (8)$$

Equation (6) then becomes $p = w\cos\alpha = w\frac{r-y}{r}$ the greatest value for a given point of the arch.

Substituting in equation (3) the value of p found in eq. (8), and, reducing, we obtain

$$P = wr[\alpha - \alpha' - \sin\alpha\,(\cos\alpha' - \cos\alpha)] \quad (9)$$

or

$$P = w\left(l - l' - \frac{x}{r}[y-y']\right)$$

in which l and l' represent the length in feet of the arcs from the crown E (Fig. 1) to the points A and D respectively.

Equation (4) then becomes

$$P' = wr\,(\alpha'' - \sin\alpha''\,[1-\cos\alpha''])\quad (10)$$

To find the gross weight of that portion of the arch which presses on the back pieces and laggings, it is necessary to know the number of the voussoirs, their volume and weight per cubic foot.

The weight of stone generally used in arches varies from 120 to 180 pounds per cubic foot. The following results were obtained from the examination of a number of specimens of American granite, sandstone and limestone, taken from the best known quarries in the country. Of seventy-two specimens of granite examined, the greatest weight per cubic foot was 182.5 lbs., the least 161.2, and the average 167.09 lbs. Of fifty-three specimens of sandstone examined, the greatest weight per cubic foot was 164.4 lbs, the least 127.5, and the average 140.9 lbs. Of thirty-eight specimens of limestone, the greatest weight per cubic foot was 173.8, the least 143.2, the average 162.9.

We may therefore without sensible error assume the average weight of these three classes of stone as follows:

	Average weight per cubic foot.
Granite	167.09 lbs.
Sandstone	140.9 lbs.
Limestone	162.9 lbs.
Brick (well burnt)	92.0 lbs.

From the moment the angle of repose is passed and the first voussoir begins to press on the frames, the centring becomes subjected to a series of strains which increase rapidly up to the time the keystone is laid, and are produced by the yielding of the ribs under the weight of the stones. No matter how well seasoned and admirably proportioned the timbers may be, or how evenly the load may be distributed, the centre, pressed more and more severely on each side by the successive courses of voussoirs laid upon it, will bend in on the sides, and as a consequence bulge out at the crown, to be in turn followed by a bending in of the crown when the arch is all but completed. This movement of the ribs can be greatly checked and the severity of the resulting strains much lessened by loading the centres at the crown with the spare voussoirs and increasing the load as the arch progresses. In the case of a full centre arch of 90 feet, and composed of four hundred and eighty courses of voussoirs, the centring, when the fifteenth course of voussoirs on each side were laid in place, had risen three inches at the crown. When loaded with 325,000 lbs., it settled under it two inches; but when the twentieth course was completed the pressure was so great that it again rose one inch. When the arch was three-quarters completed it had again sunk one inch and three-quarters in consequence of the additional load and the compression of the wood, still leaving a rise of one quarter of an inch. This yield caused the joints at the twenty-second course to open a fraction of an inch, but closed when the keystones were driven. This distortion of the centring is always greatest for full centre arches, and proportionally less as the arch becomes nearer and nearer to the segmental.

DIRECTION OF THE STRAINS.

To find the direction and intensity of

the strain at any point of the rib, we resort to the usual method of the "parallelogram of forces." Returning to Fig. 1, let it be required to find the direction of the strain caused by the voussoirs A B C D. Denote by F the centre of gravity of this part of the arch, and through it draw a vertical line G I of indefinite length, and cut it at I by a perpendicular from the point E at which the curve drawn through the centres of gravity of the voussoirs—supposed indefinitely small—cuts the line A B. Complete the parallelogram by drawing the line I M to the centre of arch, and N L parallel to it. The diagonal I N will then express the weight of the voussoirs A B C D, the side I L the pressure they exert upon the lower part of the arch, and the side I M the pressure upon the backpieces of the rib.

The strains, then, upon the centring take the direction of the radius of curvature of the intrados, and it now remains to consider the position which should be given to the beams which are to withstand the strains, their number and dimensions.

THE PRINCIPAL BEAMS AND THEIR POSITION.

As the sole object of the framing is to uphold the voussoirs and transmit the strains it receives as directly as possible to firm points of support, the beams must be so arranged as to do this with the least tendency to change the shape of the rib, by their bending or breaking. The condition will be best fulfilled by giving each beam a position such that it shall offer the greatest possible resistance, and this will be accomplished when the direction of the fibres of the beam and the direction of the strain are one and the same.

If, for instance, we support a horizontal beam at its two ends and load it in the middle it will offer its least resistance to the load. If now we raise one end so that the direction of the strain is oblique to the fibres of the beam, the resistance of the beam to bending will be found to have increased largely, and the resistance in this latter case, will be to that in the former case, as the cosine of the angle made by the direction of the strain and the fibres of the wood is to the sine of 90° or 1.

It should follow from this that, when the angle between the beam and the strain is zero, the resistance becomes infinite, and such would indeed be the case were it not for the compressibility of the wood and other physical causes which weakens its strength. It is sufficient, however, for us to know that when the strain is carried through the axis of the beam, it is then strongest, and that as the force becomes more and more oblique to the fibres its strength decreases.

Applying this fact to the framing of the ribs, it follows that the greatest stiffness and strength will be gained when the principal pieces are placed in the direction of the strains, or in the direction of the radii of curvature of the arch to be upheld. This deduction, unfortunately, is under certain restrictions placed upon it by the imperfections of the timber, and demands of economy and the circumstances of construction, which make its practical application quite limited.

To illustrate, we will once more return to Fig. 1. The direction and intensity of the strain on the backpieces resulting from the weight of the voussoirs ABCD, will then be represented, as we have just seen by the line V M, and that of the voussoirs P Q by the line V S. The beams, therefore, which are to support these stones, in order that they may offer the utmost resistance, must take the direction of the lines V S and V M, or radiate from the centre V like the spokes of a wheel. For small span arches, such an arrangement of beams undoubtedly answers all purposes of stiffness and economy, but for arches of larger span where timbers of thirty, fifty, or even a hundred feet in length would be required, it fails most signally; for while a beam of ten feet will offer great resistance to compression when loaded in the direction of the fibres, a beam of fifty feet will be almost sure to bend under the action of the strain, and hence require bracing. This system, therefore, cannot be successfully carried into practice in large span centres.

To overcome this difficulty we are forced to resolve the force represented by the line S V into two components, one vertical and represented by the line S T, and one horizontal represented in direction and intensity by S R. By a similar

treatment of the force represented by V M, we shall obtain two other similar lines, all four of which will represent the direction of three beams, which can be made to take the direction of the two V S and V M, namely, a long horizontal beam spanning the arch and supported at each end by a vertical beam. This horizontal beam is the *tie* beam to which we have already alluded, and is generally placed at points about 45° up the arch. The voussoirs above this beam are then supported by another horizontal tie upheld by small vertical beams abutting on the lower tie. An excellent illustration of this system of framing is found in centres of London Bridge over the Thames, built in 1831 by Rennie.

There will frequently arise cases in which ribs framed in this manner either on account of the quantity of material they consume, or the difficulty of finding firm points of support between the abutments, cannot be used to advantage. It then becomes necessary to change the point of support T of the beam S T (Fig. 1) to a point t nearer the abutment, and for the sake of economy we may do away with the horizontal and vertical beams tg, sS, T S, ca and ab, supplying their place by two beams tS and Se. These two beams, therefore, will sustain the strain represented by the line S V, and the efforts they resist will be represented in direction and intensity by the sides S X and S Y of the parallelogram X Y constructed on S V as a diagonal.

In "cocket" centres, therefore, whatever the span of the arch, whether large or small, whatever the shape, whether full centre, oval or segmental, a great saving of material may be made, and abundance of strength may be secured, by placing the principal beams in the direction of the chords of the curve of the intrados.

The length that should be given to beams thus placed, the angle they should make with each other at their point of junction, the manner of supporting, and when necessary bracing them, are points we shall reserve for future consideration.

There are, therefore, three methods of arranging the principal pieces or struts of a centre frame.

1°. They may be placed in the direction of the radii of curvature of the arch, thus giving a figure of invariable form as the strain at any one point is received by the beam in the most favorable position, and transmitted through its axis directly to the fixed point of support.

2°. They may be placed in a vertical, or in vertical and horizontal directions.

3°. The curve of the arch may be divided into a number of arcs, and the beams placed in the direction of the chords of these arcs.

4°. To these three we may add a fourth, which embraces by far the largest number of centre frames, and is based on two or all of the preceding methods. In this class the beams are not arranged in accordance with any one system, but several; as, for instance, the second and third, in which case, as we shall see hereafter, several straining beams span the arch at different points, and are sustained by inclined struts; or if all three systems are used, we may use the straining beam and inclined struts, and strengthen them by bridle pieces in the direction of the radii.

It would, indeed, be quite a hopeless task to attempt to lay down, in more than a general way, the principles which ought to rule in making a selection of one of these methods to the exclusion of the remaining three. In every case the choice must be determined largely by the circumstances of the case, the points of support, the shape and span of the frame, and the strength required. If the centre is to be "cocket," the arch heavy, the span large, and considerable headway required beneath the frame, the third or fourth arrangement will undoubtedly afford the best results whatever may be the shape of the arch. If the arch is light, the span moderate, and little or no headway is wanted, then the second or first will generally be most convenient.

Theoretically, the first method will in all cases afford the greatest amount of strength and stability with the least amount of material, since the beams are then capable of resisting the most severe strains. Nor can there be any doubt that, within moderate limits, this result actually is attained in practice, and that of two ribs constructed with the same number of beams, of the same quality of wood and similar dimensions, in one of which the pieces are placed

radially, and in the other vertically or inclined, the rib arranged on the former plan will be decidedly the stronger of the two. But, unfortunately, the impossibility of always obtaining firm points of support at the centre of curvature, the difficulty of finding sound, well seasoned timber of such length as would be required in arches of large span, and the relation which exists between the length and strength of beams under longitudinal compression—the strength varying inversely as the square of the length—restricts its application to centre frames of very small span and rise. In semi-circular arches of twelve, fifteen or even twenty feet span, when a horizontal beam can be used at the springing line this arrangement can be used with great success. The frame then consists of the tie beam and two, or if great strength is required, three radial struts which support the backpieces and abut against the horizontal beam at the centre of curvature. These struts, when two are used, should be inclined on the right and left at a little less than 45° to the horizon, so as to meet the backpieces at the point where the voussoirs first begin to press on the rib. A vertical strut is in such an arrangement of little or no use, as no strain of any consequence can possibly reach it; the voussoirs almost ceasing to press on the frame when the keystone is driven down. As these supports are struts and not bridle pieces clamping the backpieces and tie beam between them, the joints, especially in the larger and heavier arches, must be secured by pieces of iron placed across them and bolted to the backpieces and struts, to prevent the joints opening in consequence of the bulging at the crown as course after course of stone is laid on the frame.

In frames for flat segmental arches of a span as great as sixty or seventy feet and rise of about one-fifth the span, as also for ovals of several centres, this radial arrangement may be slightly modified and a frame produced (Figure 2),

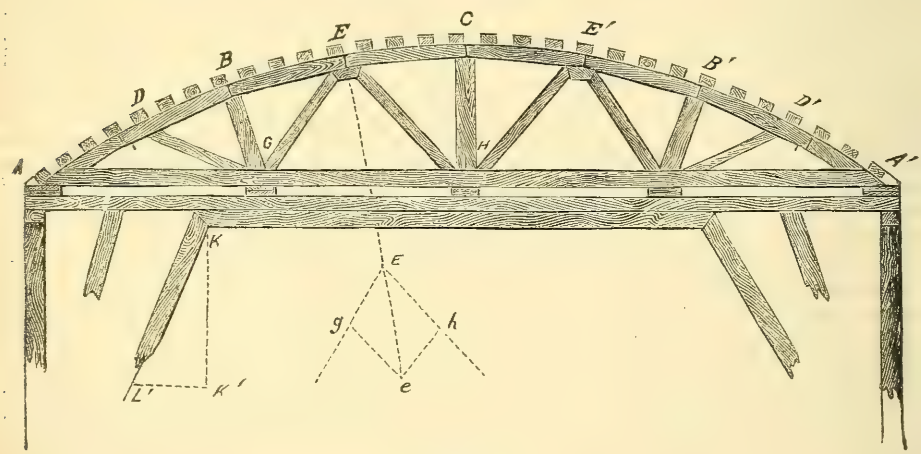


Fig. 2.

which shall meet all the requirements of strength, lightness and economy. The rib in this case again consists of a horizontal tie beam spanning the arch a little above the springing line, generally at the first voussoir that presses on the backpieces, and struts placed in the direction of the radii of curvature and from eight to ten feet apart depending on the weight of the arch. These struts, as it would be impossible to have them actually meet at the centre of curvature, which, for an arch of seventy feet span and fifteen feet rise, would be about forty-five feet from the circumference, go no further than the tie beam and are fastened to it and the backpieces by the iron bands shown in the figure.

When great stiffness is required in the rib, additional braces may be added, as shown in Fig. 2, dividing the rib into a number of triangles. The strains received will then be transmitted through the axes of the beams, and as all unnec-

essary transversal strains will be avoided, the resistance offered by the braces will be the greatest possible. In all centre ribs, the *normal* pressure being in the direction of the radii of curvature, the laggings, backpieces and tie beam, when used, will of necessity be subjected to transversal strain.

Before, however, we proceed to consider the strains to which the beams in centre frames are subjected, and the dimensions we must give them in order that they may withstand the pressure put upon them, we would offer the following practical rule for estimating the pressure of any arch stone in any part of the arch, upon the centre rib, or the pressure upon the rib at any stage of the construction of the arch, as also the pressure when the arch is completed up to the key stone.

It has been well established by the experiments of Rondelet, that a stone placed upon any inclined plane does not begin to slide on that plane until it has reached an angle of inclination to the horizon equal to 30°. It is obvious, therefore, that if the arch stones were placed upon one another they would not begin to press on the centre rib till the plane of the lower joint of one of them reached an angle of 30° with the horizon. It has been found, moreover, that the mortar increases this angle, for hard stone to 34° or 36°, and for soft, porous stone (in semi-circular arches) to 42°. We may, then, consider the pressure to commence in general at the joint which makes an angle of 32° with the horizon. If we suppose the radius to represent the pressure the tangent will then represent the friction, and making the radius unity the friction will be 0.625. The next stone will press a little more, the third still more, and the pressure will thus continue to grow larger and larger with each succeeding course. The relation between the *weight* of an arch stone and its pressure upon the rib in the direction perpendicular to the curve is given by equation :

$$Q = W\ (\cos a - f \sin a) \qquad (11)$$

in which Q is the pressure, W the weight of the arch stone, f the friction = 0.625, and a the angle the lower joint makes with the vertical. The following table calculated from eq. 11, gives the value of Q for every 2° of curve from the angle of repose = 32° up to 60° :

When the angle which the joint makes with the *horizon* is

	34°.....	then	Q=.04 W
When	36°.....	"	Q=.08 W
"	38°.....	"	Q=.12 W
"	40°.....	"	Q=.17 W
"	42°.....	"	Q=.21 W
"	44°.....	"	Q=.25 W
"	46°.....	"	Q=.29 W
"	48°.....	"	Q=.33 W
"	50°.....	"	Q=.37 W
"	52°.....	"	Q=.40 W
"	54°.....	"	Q=.44 W
"	56°.....	"	Q=.48 W
"	58°.....	"	Q=.52 W
"	60°.....	"	Q=.54 W

To take an example: What is the pressure on a backpiece of 20° in length from the angle of repose, the ribs of the frame being placed 5 ft. from centre to centre, and the arch stones 3 ft. in depth and weighing 160 lbs. per cubic foot. We take from the above table the sum of the decimals from 32°–52°=2.26, and multiply this by the weight upon 2° and the product will equal the pressure. The volume of the stones which cover 2°=5×3×2°.

The number of feet contained in 2° is found from the expression $2 \times .01745329 \times r'$, in which r' is equal to the radius of the arch *plus one half* the *depth* of the *arch stone.* If we take the radius = 25 ft., then the depth of the stones being 3 ft, $r'=26.5$ and number of feet in 2° equals .88 ft., whence the volume of the stones which press on the 2° equals $5 \times 3 \times .88 = 13.4$ cubic feet, and the quantity W=2144 lbs. and Q, or the pressure on the backpiece equals 4845 lbs.

If we denote by a the angle included between the upper and lower joints of an arch stone, and suppose every stone in the arch to have the same weight and equal angle a, then the pressure of any number n of such stone upon the rib will be given from the expression

$$Q = \frac{W + \sin \frac{n+1}{2} a}{\sin \frac{1}{2} a} \times (\cos \tfrac{1}{2} na - f \sin \tfrac{1}{2} na) \qquad (12)$$

which gives the total pressure on *one half* of the rib.

This equation is found as follows: The pressure perpendicular to the soffit is W (sin $a-f$ cos a), or W (cos $a-f$ sin a), according as the angle a is measured from the *horizon* or from the *vertical* drawn through the crown. If now we denote by a the angle included between the joints of *one* stone, and suppose each stone alike in size and weight, the pressure of any number n of such stones will evidently be found by getting the sum of the *sines* and *cosines* of $n\,a$, or expressed in formula,

$$P=W\ (\text{sum of cosines of } n\,a-f\times\text{sum of sines of } n\,a) \quad .\ .\ .\ .\quad \text{Eq. A.}$$

By trigonometry we obtain two expressions for the sum of the sines and cosines of a number of angles in arithmetical progression, viz.:

$$\text{Sin A}+\sin(\text{A}+\text{B})+\sin(\text{A}+n\,\text{B}) =\frac{\text{Cos }(\text{A}-\frac{1}{2}\text{B})-\cos(\text{A}+n+\frac{1}{2}\text{B})}{2\sin\frac{1}{2}\text{B}} =\frac{\text{Sin }(\text{A}+\frac{1}{2}n\,\text{B})\times\sin\frac{1}{2}(n+1)\,\text{B}}{\sin\frac{1}{2}\text{B}.}$$

Also

$$\text{Cos A}+\cos(\text{A}+\text{B})+\cos(\text{A}+n\,\text{B}) =\frac{-\cos(\text{A}+\frac{1}{2}n\,\text{B})\times\sin\frac{1}{2}(n+1)\,\text{B}}{\sin\frac{1}{2}\text{B}.}$$

Applying these two equations to the above case, we shall have from eq. A,

$$P=W\ \frac{\cos\frac{n}{2}a\times\sin\frac{n+1}{2}a-f(\sin\frac{n}{2}a\times\sin\frac{n+1}{2}a)}{\sin\frac{1}{2}a.} \qquad \text{Eq. B.}$$

Or taking out the common factors W and $\dfrac{\sin\frac{n+1}{2}a}{\sin\frac{1}{2}a}$ we shall have equation B in the form. Eq. (12)

$$P=\frac{W\times\sin\frac{n+1}{2}a}{\sin\frac{1}{2}a}\times\left(\cos\frac{n}{2}a-f\sin\frac{n}{2}a\right)$$

The value of Q may also be obtained from eq. 11 by considering that when the depth of the arch stone is nearly double its thickness; its *weight* rests on the rib at the angle of 60°. Equation 12 is, however, the best, and may be readily solved by logarithms.

For example: let the arch be semicircular and $a=2°$, then $n\,a=29°$ and $f=.625$. Put equation 12 in the form

$$P=W\left\{\frac{\cos\frac{1}{2}n\,a\times\sin\frac{n+1}{2}a}{\sin\frac{1}{2}a\times R}-\frac{f\sin\frac{1}{2}n\,a\times\sin\frac{n+1}{2}a}{\sin\frac{1}{2}a\times R}\right\}$$

$$\begin{aligned}
\log\cos\ n\,a &= \log\cos 29° = 9.941819\\
\log\sin\tfrac{n+1}{2}a &= \log\sin 30° = 9.698970\\
&\overline{19.639789}\\
\log\sin\tfrac{1}{2}a &= \log\sin 1° = 8.241855\\
\text{R} &= 10.000000\\
&\overline{18.241855}\\
\text{Difference} &= 1.397934\\
&= \log 24.68
\end{aligned}$$

$$\begin{aligned}
\log f &= \log .625 = -\ 1.795880\\
\log\sin\tfrac{1}{2}n\,a &= \log\sin 29° = 9.685571\\
\log\sin\tfrac{n+1}{2}a &= \log\sin 30° = 9.698970\\
&\overline{19.180421}\\
\log\sin\tfrac{1}{2}a &= \log\sin 1° = 8.241855\\
\text{R} &= 10\\
&\overline{18.241855}\\
\text{Difference} &= 0.938669 = \log 8.55
\end{aligned}$$

Hence the weight on the half rib is $24.68-8.55=16.13$ W.

In a frame constructed, as that shown in Fig. 2, the determination of the strains is a matter of great simplicity, and may be had either from arithmetical calculation or by constructing the parallelogram of forces. The strain on any radial strut as B G would be found by calculating from eq. 11 the pressure on D E, taking half of it and supposing it to act at B in the direction B G. The strain on any inclined strut, as E G or E H, may be found by estimating from eq. 11, the strain on B H taking one half of it, and supposing it to act at E in the direction of the radius at that point, and denote by δ and δ' the angles these pieces make with the direction of the force. Then, if these angles are unequal

$$S = \frac{P \sin \delta'}{\sin (\delta + \delta')} \quad \text{and } S' = \frac{P \sin \delta}{\sin (\delta + \delta')} \quad (13)$$

And if the two beams make equal angles with the direction of the force, then the strain in the direction of each is the same and expressed by

$$S = \frac{P}{2 \cos \delta} \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

Of all methods of calculating the strain on the different beams, by far the simplest, is to actually construct the diagram of forces to a given scale and find the pressure by measurement. In above case, for example, draw E e parallel to the direction of the force to any convenient scale, say $\frac{1}{10}$ inch equal 1,000 lbs., which, supposing the pressure at E=10,000 lbs. will make E e=one inch. From E draw E g parallel to E G; also E h parallel to E H, and eg to E h and eh to E g. Then E g being measured will give the pressure on the beam E G to which it is drawn parallel.

When we have once ascertained the strain which any beam in a frame will have to undergo and resist, the next step is to determine the dimensions, or rather the area of cross section, the beam must have to withstand this pressure without injury. Whatever may be the length of the beam, this section may be obtained from the following formulæ: If the strain is one of compression in the direction of the length, then

$$A = \frac{F}{K}$$

in which A is the section required in square inches, F the crushing force to which the beam is subjected, and K the *resistance* to *crushing*. When the strain is a transverse or breaking strain, then

$$A = \frac{F}{K'}$$

in which K′ is the *modulus* of *rupture* of the beam.

In place of K and K′, however, which are the ultimate resistance to crushing or rupture, we must use $\frac{K}{n}$ and $\frac{K'}{n}$, in which n is the factor of safety, usually taken as 10 for wood. The values of K and K′ are variously stated by different writers on the strength of materials. Those given below for the woods mostly used in centre frames are from Rankine:

Wood.	Value of K in lbs	Value of K′ in lbs.
Ash	9,000	12,000
Pine, yellow	5,400	9,900
Pine, red	6,200	7,100
Oak, English	10,000	10,000—13,000
Oak, American	6,000	10,600

If it is not always possible to obtain these values of K and K′, a very safe method, and one easily remembered, is to find from the diagram of forces the strain on a beam in lbs., and divide this by 1,000; the result will be the cross section of the beam in inches. Thus, if a timber is loaded with 36,000 lbs., $\frac{36,000}{1,000} = 36$ in., and the beam should be 6 in. × 6 in.

Example.

Required the proper dimension of the scantling of a centre rib of a segmental arch of 60 feet span and 9 feet rise; the arch stones to consist of old quarry granite, weighing 165 pounds per cubic foot, and three feet in depth; the rib to be of the pattern shown in Fig. 2. The frames to be placed 5 ft. from centre to centre.

The first step is to find the weight of the arch stone for 1° of the curve. The span is 60 ft., the radius is 50 ft., and the arch stones being 3 ft. thick the radius of the arch passing through their centre is 51.5 ft. The length of 1° is, therefore, .01745329× 51.5 =.89 ft. Then 5×3×.89 = 13.3 cubic ft., the solid contents of 1° of the arch ring, and this multiplied by 165 gives the weight of 1°=13.3×165 = 2195 pounds. Now the arch being a very flat segmental, it is evident that *all* the arch stones will press upon the rib. If then we calculate the weight of the stones between E E′, and suppose them to act with one half their entire weight at C in the direction C H, it is evident that this will be the greatest pressure that C H will be required to support. The arc E E′=20°, and the weight for 1° being 2195 lbs., the pressure at C is 21950 lbs., and the beam C H should be

$\frac{21950}{1000}=21.9$ inches or $4\frac{1}{2}\times 5$ in. To find the dimensions of E G and E H take eq. 12. Then $a=1^\circ$, $n=20^\circ$, $f=.625$, $W=2195$.

$$Q=\frac{2195+182236}{.008727}\times(984808-.625\times 173648)=18301 \text{ lbs.}$$

Take this and lay it off to any convenient scale on the line E e, and from E draw E g parallel to E G, and E h to EH and as before $e\,g$ and $e\,h$. Then measuring E h by the same scale it will be found to equal 10250 lbs.; the beam EH then must be $3\frac{1}{2}$ in. by 3 in. In the same manner the pressure on B G is found to be 18301 lbs., and the beam must be $4\frac{1}{2}$ in.$\times$4 in. To find the strain on the inclined strut, estimate from eq. 12 the weight of the arch stones between A and C, add to this half the weight of the rib and let the gross weight act vertically at the point K, and lay it off to any scale on the vertical line K K′, and draw K′ L′ parallel to the horizontal tie beam. The line K L′ being measured will give the strain on the beam K L′.

Frames arranged on the second method, with the principal pieces all vertical, afford centres of great simplicity of structure and of almost as much strength as one with radial struts—supposing, of course, that the number and dimensions of the struts are the same in each case—and of much greater strength than one constructed with inclined beams, since the nearer the angle the direction of the strain makes with the fibres of the wood approaches a right angle the less becomes the resistance of the beam. In segmental and oval arches of large span, the difference in the strength of ribs arranged on the vertical and radial plan is comparatively insignificant, as the radius being very large, the vertical beams, especially near the crown where the strain is severe and most strength is required, do not depart much from the direction of the radius.

The objection to this vertical bracing of the frame is that it requires the use of a horizontal tie beam, unless the rib is constructed as a girder resting upon framed abutments of its own. If the former arrangement is used, the struts should be placed from five to eight feet apart, depending on the strength required, and mortised to the tie beam and backpiece. When the beams are of such length that there is danger of their bulging or curving under the load laid on them, they may be strengthened by diagonal braces or horizontal wales. Of the two, the diagonal braces are to be preferred as they not only give stiffness to the posts, but sustain a portion of the load on the backpieces in case any of the piles under the horizontal tie beam should give way. Figure 3 represents the rib of a full centre arch of 75 ft. span ar-

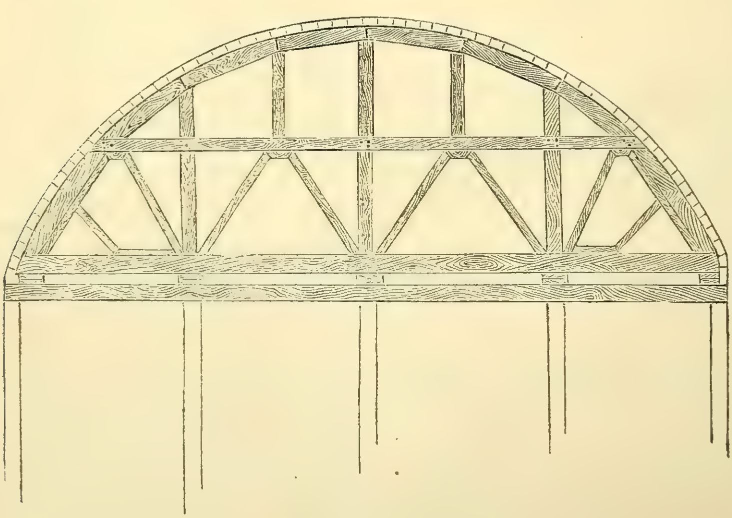


Fig. 3.

ranged with the principal pieces placed vertically and strengthened with a horizontal waling piece made double, and braces abutting under the backpieces. The strains on the different beams composing such a frame, and their necessary dimensions may be computed with ease by the method just explained. It should, however, be remembered that beams which are to be notched must have their dimensions increased beyond those given by calculation, in as much as notching will, even when not very deep, cut down the strength of a beam from one third to one half. In computing the strains on the braces *a*, *a*, we may consider the pressure at their abutting point to be the sum of the pressures on the vertical and two inclined braces which meet there, and make no allowance for the resistance of the horizontal beam.

The third and fourth systems of arranging the principal pieces, afford an almost unlimited number of designs for centre ribs, which are especially worthy of notice, in that they are applicable to every possible shape and span that can be given to stone arches, and may be constructed with or without intermediate points of support, according as circumstances will admit. The principles which control such arrangements are few and simple. The beams should as far as possible abut end to end: they should intersect each other as little as may be since every joint causes some degree of settlement, and halving destroys fully half the strength of the beams halved. When the framing is composed of a number of beams crossing each other, pieces tending towards the centre should be notched upon and bolted to the framing in pairs : ties should also be continued across the frame at points where many timbers meet. Particular attention must, furthermore, be given to the manner of connecting the beams so that there shall be no tendency to rise at the crown under the action of the varying load, Figure 4 affords an illustration

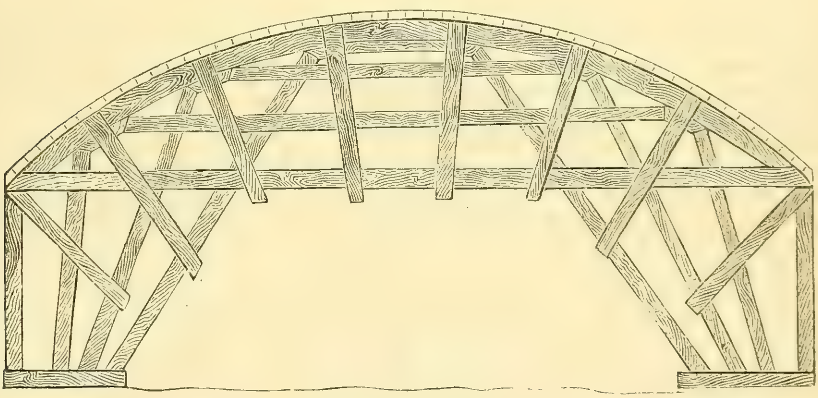


Fig. 4.

of a very simple method of arranging the timbers for arches of small span. The inclined struts abut against horizontal straining beams placed at different points on the soffit, and to add greater strength to the framing, and to prevent the horizontal beam from sagging, bridle pieces are placed in the direction of the radii of curvature. The chief difficulty with such arrangement as this is, that as they require beams of great length they can be used to advantage only in small span arches.

The centre frames for the Waterloo Bridge over the Thames were constructed on this principle, but in this case no horizontal beams were used. Under the backpieces were placed blocks each supported by two inclined struts which made equal angles with the radius drawn through the centre of the block. In a small span arch, these struts would have rested on framed supports placed at the opposite abutments of the arch ; but in the Waterloo Bridge, to avoid the inconveniences resulting from crossing the

struts, and of building beams where struts of sufficient length could not be obtained from single beams, the ends of several struts were received into cast-iron sockets placed at their point of crossing and suspended by bridle pieces.

Figure 5 is a good design for a cocket centre of large span. Here the C F′,

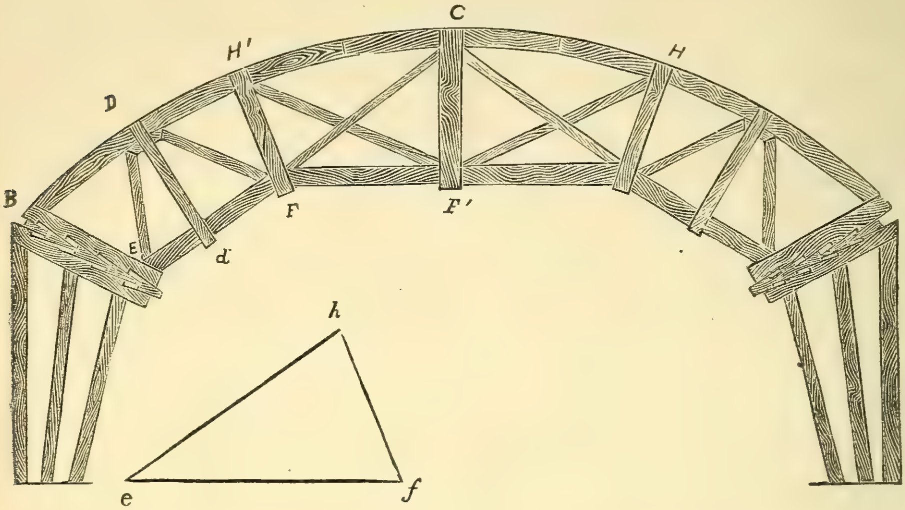


Fig. 5.

H F and D d, are placed in the direction of the radii of curvature and made double; the remaining braces are single. In determining the proper dimensions for the scantling of such a frame, we may take $\frac{2}{3}$ of the total pressure on the arc H H′, and suppose it to act at C in the direction C F′, which will evidently be the greatest load this timber will have to sustain. The strain upon the E D F will then be equal to $\frac{1}{2}$ the load on B H, and that on H F as $\frac{1}{2}$ D C. That on the beams E F and F F′ is to be found from the diagram of forces, Fig. 5. Here hf which is in the direction of H F produced, represents the pressure on this beam; E h is drawn parallel to E F, and ef parallel to F F′, which being measured give the strain on E F and F F′ respectively. If it is desirable to obtain the dimensions of the beams with great accuracy we may use the following formulæ: If we assume the relation between the breadth and depth to be .6 to 1 (which is an excellent proportion), then for an inclined beam whose angle of inclination to the horizon is β.

$$d = \sqrt{\mathrm{L}\sqrt{\frac{\mathrm{W.} \times \cos\beta \times a}{0.6}}} \quad . \quad . \quad (15)$$

And for a horizontal beam

$$d = \sqrt{\mathrm{L}\sqrt{\frac{\mathrm{W.}\, a}{0.6}}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

In which a is to be found from the expression $\frac{40\times b\times d^3\times \delta}{\mathrm{L}^3\,\mathrm{W}}=a$, in which δ is the deflection of a beam whose breadth is b, depth is d, length L, and load W. For pine this quantity a is from .0112 to .0105, and for the best oak .00934. Eq. 15 or 16 will give the depth in inches. If it so happens that the value of a, in the above equation, cannot be obtained either by actual experiment or from tables, we may make the square of one side equal to twice the square of the other, which will give a ratio of 7 to 5 very nearly, and use the equation

$$d=0.0046108\times\sqrt[3]{\frac{w.\, l^2}{\cos b}}$$

Where w is the load, l the length, and b the angle the beam makes with the vertical, and d the dimension of the *smaller* side, equal $\frac{5}{7}$ of the larger. In centre frames, however, such a degree of exactness is rather unnecessary, since, by allowing 1,000 lbs. to the square inch we

can obtain the cross section from the load with all the accuracy desirable in practice.

The transversal strain on any one back-piece or segment of the rib under the laggings may be obtained from the expression

$$S=P \sec \phi \quad . \quad . \quad . \quad (17)$$

ϕ being the angle the backpiece makes with the horizon, and P the vertical component of the pressure on the same piece found by any of the methods already explained, or from

$$P=W\left(L-\frac{x}{r}h\right) \quad . \quad . \quad . \quad (18)$$

W being the pressure on each lineal foot of the segment, L its length; r the radius of curvature at the point in question, x the distance of the lower end of the backpiece from the vertical through the crown of the arch and the centre of curvature, and h the distance between the two ends of the segment measured vertically.

The strain upon any one of the laggings will depend, independent of the weight of the arch stones, on the distance of the ribs from centre to centre, the place the lagging occupies in the arch and the manner in which the laggings are attached to the backpieces of the frame. As regards the latter point, there are two ways of making them fast to the rib. They may be placed directly on the backpiece and nailed to it, or they may be mounted on folding wedges placed between each bolster or lagging and the rib, which latter arrangement will be considered in detail when we come to speak of the striking plate. The bolsters, moreover, may be placed on the rib in such wise that they touch each other, or may be separated by a space equal to their own breadth. The former method is most usually resorted to in the construction of brick arches, and is illustrated in Fig. 4; the latter is used in building stone arches, and is illustrated in Fig. 2. By separating the laggings in this wise a considerable saving of timber is effected, while the air is also given freer access to the joints of the arch and the mortar much sooner dried. When these pieces are separated, it is evident that the cross section of each must be slightly greater than when they are placed touching each other, and that the section of the laggings placed near the crown should be larger than those near the angle of repose. This latter point is not worth considering in practice unless the arch stones are very heavy, for in arches of the ordinary span and weight the saving thus effected in the timber is hardly worth the labor of calculation. In determining the proper dimensions of the laggings, it is sometimes customary to insure against any deflection, by supposing the entire load on each lagging to act at its middle point and calculate for a beam strained in this manner.

TESTING RAILWAY STEEL AXLES.

From "The Engineer."

A PAMPHLET now before us, written in German, contains matter of much interest to British steel makers executing foreign orders for axles. It is too well known to some of our readers that their work is subjected by the inspectors of their foreign customers to very unusual and severe tests, resulting in so much loss and interruption that first-class makers in Sheffield have often refused such orders. Now the results before us cut at the very root of the whole system, and point to the conclusion that the tests adopted by foreign railways especially defeat their own purpose. The paper, the results of many careful experiments, represents a considerable amount of work and time on the part of a countryman of ours in Vienna, a son of the Mr. John Haswell so well known in the profession. Experiments were made on twenty-nine steel carriage axles, of which two were of crucible steel and the remaining twenty-seven of Bessemer metal. Four new iron axles were also tried, and, in addition, two locomotive iron axles.

As is generally known, the mode of procedure usually adopted by continental railway engineers is to take one out of each hundred axles, and test it to destruction. It is usually stipulated in the *cahir des charges* that the whole lot may be rejected if this one, or at most a second, do not stand the trial, as several

English makers have found to their cost. Some of these tests are very severe: such is that required by the Austrian Northern Railway, according to which all five-inch steel axles, when set on supports nearly five feet apart, must undergo blows from a weight of about 7 cwt., falling from a height of nearly 19 ft., increased by two feet for each successive blow. In this way it must withstand a bend of 9 in., and a further bending back of 9 in.—the operations being continued until the axle has withstood more than six thousand foot-pounds. A lighter test is that of the Southern Railway Company, who require for their $4\frac{1}{2}$ in. steel axles that, with a distance between the supports of nearly 5 ft., they shall withstand a bend of more than $9\frac{3}{4}$ in., under a 7 cwt. monkey, falling from a height of nearly 15 ft. They must then allow themselves to be bent back straight in the same manner without breaking. In fact, almost every other company's engineer has a different test, differing as to the distance between the supports, the weight of the monkey, the height of its fall. The requirements as to extension, compression, and ultimate resistance vary just as much, so that we cannot wonder if the very axles rejected by one company are bought and set to work by another. In truth, the process is merely that generally adopted for rails, of which a certain percentage is taken at haphazard out of the lot, and bent or fractured. This case, however, is scarcely the same as that of an axle—a much more important and responsible component part of a working line.

The increase of traffic has led the German lines of late years to increase the load on the goods trucks by nearly 25 per cent., and they hoped to find their account in replacing iron axles with others of steel. The results in actual practice scarcely responded to these apparently well-founded expectations. In fact, some of their railway engineers are now strongly recommending a return to wrought iron. The truth seems to be that the steel works, in the face of such a system of testing, found it safest simply to deliver the softest and most ductile steel, able to withstand the maximum number of blows from the monkey. Hence the steel axles used are actually of much softer material than those of iron, too soft for their work, liable to permanent sets, and deficient in elasticity. An axle made of lead would as regards ductility certainly beat iron, and withstand more blows without actual fracture. The results in practice are little less than disastrous. It is stated that one of the greatest lines in Austria, possessing extensive steel works of its own, has had, under this system of testing, so many fractures of steel axles that they are being replaced by axles of wrought iron. The practice is certainly not that recommended or adopted by our best railway engineers. As a rule few, if any, English lines test their axles, and a warranty from the maker is usually deemed sufficient. A chance return to this procedure afforded its own lesson. A year or two ago, one of the largest German lines ordered, somewhat in a hurry, a number of axles from an English firm. These axles did not by any means stand the tests; but, on the inspecting engineer telegraphing home for instructions, he was told to receive them. They are now in use, behaving exceedingly well under heavy traffic.

The conclusions to which Mr. Haswell arrives are that the very severe tests have simply resulted in producing steel axles much softer than those of iron; that the proof of one or two axles out of a hundred is no criterion of the quality of steel axles, as axles from the very same works, forged with the greatest care, gave quite different results.

The examination of the question and the experiments carried out by Mr. R. Haswell were undertaken under the auspices of a committee of members appointed by the Vienna "Institution of Civil Engineers and Architects." The results were also very completely laid before them at a meeting held for the purpose. Any action to be taken on the conclusions of their own committee was, however adjourned *sine die* by these gentlemen. Whether they were afraid to accept the responsibility, or, for any other reason, they declined to express any decisive opinion, we hope that this sufficiently important and interesting question will be takan up again, and be brought sooner or later to a definite settlement. It would be regretable if the expenditure of so much work, time, and money should lead to no result.

WATER SUPPLY AND DRAINAGE.*

By W. A. CORFIELD, Esq., M.A., M.D.

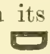
IV.

UTILIZATION OF SEWAGE.

Before describing to you the composition of sewage and the ways in which it has been proposed to treat it, I have a few words to say to you about the construction of the apparatus in houses, especially as to the construction of the apparatus used for the removal of such effete matters from houses. I am going to say a word or two on this subject because of the importance of the points connected with it—points that every one of you ought to know.

In the first place, the simplest form of closet that can be used is one with an earthenware pan and syphon, all in one piece, which of course, so long as it is not broken, always retains a certain quantity of water in it. The advantage of this closet is that it can always be readily cleansed. In towns where a more complicated form of apparatus has been tried for the poorer classes and for persons who are not careful, water closets have always failed. One of the great arguments for the supporters of all the dry systems, and especially of the dry earth system, has been that the water system has failed because persons will not take reasonable care; but that has been where the apparatus has been too complicated, as has often been the case in London. Now in towns supplied with apparatus of that sort there is much less risk of anything getting out of order; anything that finds its way into the syphon can be easily got out again, and in fact nothing short of pushing an iron rod in, and making a hole in it, is likely to do any harm, and when a hole is made in it it is easily detected, because the water will not then remain in the syphon; in fact nothing is easier than to discover such a damage.

In the next place they are cheap. One very important point about this system, especially if these closets have to be inside houses or dwellings, is that there should be a hole in the syphon, at the highest point of the pipe above the water, and leading into the drain, and that at this point there should be attached a ventilating pipe. Any sewer gases arising will then be taken off by that pipe, which should be carried to a sufficient height and turned over at the end.

As to the water supply any simple apparatus will do for that; the usual plan is to have a wire, which, when pulled, lifts a plug in the cistern, and water runs down a pipe which generally ends in the side of the pan, the aperture being so directed that it whirls the water round the pan; and the waste pipe of the cistern supplying these may, if that cistern is outside the house, and is only used to supply the closet, be made to end in the same supply pipe. There is very little harm in that, but it should not be done if the same cistern is used for supplying drinking water, which ought not to be the case, although it so often is. A more complicated form of water closet, which is commonly used, requires a word of notice. In this sort you have what is called a D trap, and above that there is what is known as a container, which is a large iron vessel opening below into the water in the trap. Water always remains in this D trap up to the level of the outlet. It is called a D trap from its shape; it is like a D placed thus  The pipe which leads from the container (which is the iron vessel immediately under the pan, and in which the basin moves) dips under the surface of the water in the D trap.

Now a few points of caution about this method are necessary. This is the apparatus which is accused of having brought us a large amount of typhoid fever, diarrhœa, and even cholera in large towns, which we should not have had otherwise, and no doubt to a certain extent the system is to blame for it. And I am going to show you where it is to blame for it, and what precautions we have to take to prevent this.

One way in which it is to blame is

* Abstract of lectures delivered before the School of Military Engineering at Chatham.

that the descent pipe, called the soil pipe, is a very convenient place to make the waste pipe of the drinking water cistern end in, and so, very frequently in houses this waste pipe comes down and ends there. The soil pipe goes out of the D trap, and then joins the main soil pipe of the house, or becomes itself the main or perhaps the only soil pipe. This main soil pipe is very seldom open at the top, unless it has been purposely so constructed, and so any foul air in the drain below, or in the soil pipe itself cannot get away, and so it simply goes up the waste pipe of the drinking water cistern, and in fact the waste pipe of that cistern forms the ventilator of the soil pipe, and any poisonous matters in the air in it are absorbed by the water, and drunk, and this is unquestionably one of the causes of the spread of typhoid fever. The waste pipe, however, should not end there, but should end, as I have before told you, outside in the open air.

Now supposing there is no waste pipe ending there, the foul air which accumulates in the soil pipe will have a good many of its ingredients absorbed by this water in the D trap, and they will be given out at the surface of the water into the "container." As soon as the apparatus is worked, and the pan let down so that the water runs out of it, then the foul gases, which have been collecting under pressure in the container, immediately issue into the house.

Now how can that be prevented? There are two ways of preventing it. In the first place, this soil pipe should be open at the top, and then you will never have sewer air with pressure on the D trap. That is quite clear. Or, if you do not carry the soil pipe itself up to the top, there should be, say, a 1-inch leaden pipe going from it up to the top of the house, and turned over, ending at some convenient place, not near the outlet of the chimney. So thus you prevent any foul air from collecting in the soil pipe and rendering the water in the D trap fouler than it need be; but the D trap is always full of water, the apparatus is seldom worked so long as to replace all that water, and so it remains always more or less foul. The foul matters in the D trap putrefy, and so foul air collects in the container, and as soon as the apparatus is worked, this foul air in the container immediately rushes out, because it has been collecting in considerable quantities, a thing which you must all have observed over and over again. That can be prevented perfectly well, so well indeed, as to render closets manageable even in the most inconvenient situations in which they can be placed, and in such situations they frequently are placed in many of the large houses in London; underneath staircases, and close to drawing rooms, or even opening directly out of bed-rooms, and in such places. Although they should, if possible, be removed from such situations, they can be made perfectly sweet in a very simple way, and that is done by making a hole in the container, attaching a small ventilating pipe to it, which pipe is taken through the wall of the house and made to end in some convenient situation, and then you never get any foul air accumulating under pressure, to rush out when the pan is moved and the water in it let fall into the container.

The valve closet is a great improvement upon this, inasmuch as the container is merely a small box in which the valve works, whereas the volume of water used is much greater.

Those are the chief points about this rather complicated apparatus, which is evidently not fit for the use of careless persons. Now for the kind of apparatus fit to be employed when large numbers of persons use the same place. There has been an apparatus contrived called "The Trough Water Closet." I spoke to you before about "Trough Latrines." They are not water closets; they are constructed in very much the same way, but in the "Trough Latrines," the excreta are collected for the day, and then are emptied into a cart and taken away. That is a modification of the "Pail System."

The "trough water closet" may be briefly described thus. Underneath the row of seats there is a trough made of iron or slate, or any convenient material of the sort. This trough at its lower end has a connection with a sewer, the mouth of which is fitted with a plug; which plug can be moved up and down by a lifting apparatus in a separate compartment, which can only be got at by the person who has charge of the place; because, of course, among large bodies

of men, there must always be a man appointed to have charge of this, just as in the case of the earth closets. This compartment can only be got at by this particular man, and he has access in order that he may lift up or let down the plug.

At the other end you have a water tap supplied from a cistern; the man who has charge of the place comes at night, lifts up the plug, lets the contents all run away into the drain, then washes out the trough, lets down the plug, charges the trough with a little water, and leaves it till the next day. That is the "Trough Water Closet," and that is the most convenient form of closet for use by large bodies of persons, especially of careless persons.

As an instance of the success of these closets, I may mention the town of Liverpool. Dr. Buchanan and Mr. Radcliffe, say—"Nothing could be more admirable than the working of the Liverpool arrangement, and nothing could be more marked than the difference between them and what are called water closets, in the poor neighborhoods of London and other large towns." Dr. Hewlett also gives a favorable opinion with regard to these closets. He says—"The trough water closets in use at Liverpool, and the self-flushing tumbler water closets at Leeds, where they answer remarkably well, appear to me to be the best kind for use in poorer districts, especially for closets which are frequented by more than one family." These opinons are sufficient.

The tumbler water closet is very nearly on the same principle. There is a very nearly level trough with a connection with the drain at the lower end; at the other end there is a sort of swing bucket which is placed below a tap. The water is running from this tap continually, but slowly, and the rate at which it shall run is subject to arrangement. As soon as the bucket contains a certain amount of water, it tips over, empties its contents into the trough, washing away whatever is in the trough down into the drain. This plan is also reported to be an excellent one. Of course the water supply and the buckets are placed in a separate compartment, and can only be got at by one person.

We pass on, now, to consider the composition of sewage. This has been well stated in the first report of the Rivers' Pollution Commissioners, in the following words "Sewage is a very complex liquid; a large proportion of its most offensive matters, is, of course, human excrement, discharged from water closets and privies, and also urine thrown down gulley holes. Mixed with this, there is the water from kitchens, containing vegetable, animal, and other refuse, and that from wash-houses, containing soap, and the animal matters from soiled linen. There is also the drainage from stables and cowhouses, and that from slaughter houses, containing animal and vegetable offal. In cases where privies and cesspools are used instead of water closets, or these are not connected with the sewers, there is still a large proportion of human refuse, in the form of chamber slops and urine. In fact sewage cannot be looked upon as composed solely of human excrement diluted with water, but as water polluted with a vast variety of matters, some held in suspension, some in solution."

Now there are great variations in the composition of sewage at different times of the year, and also at different times of the day and night. But there is not a great amount of difference between the composition of the sewage of towns where there are water-closets, and the composition of the sewage where there are not. In the first report of the Rivers' Pollution Commissioners, it is shown that there is "a remarkable similarity of composition between the sewage of midden towns and that of water closet towns. The proportion of putrescible organic matter in solution in the former, is but slightly less than in the latter, whilst the organic matter in suspension is somewhat greater in midden than in water closet sewage."

I must now give you an account of what the average sewage may be taken to be. You may take it that an average sewage has this composition; in 100,000 parts of it there are about 72 of total solid matters in solution, which total solid matters include between four and five of organic carbon, something over two of organic nitrogen, from six to seven of ammonia, and from ten to eleven of chlorine. Besides these 72 parts of dissolved matters, it contains

44 or 45 parts of suspended matters, of which about 24 are mineral, and 20 or 21 organic. Now that is the average. There are extremes. The variation of the London sewage in total combined nitrogen, is from three parts to eleven in 100,000, so that you see there are very considerable differences. And this is partly due to the fact, which is plain enough, that there is a greater amount of refuse thrown into the sewers at one time than at another, but still more to the great variations in the amount of water. As an instance of variation with the time of the year, I may tell you that during the winter before last, the average amount of ammonia in 100,000 parts of the sewage of Romford, was from five to six parts, whereas in the previous summer, the average was only two and a half to four. So that the value varies considerably at different times of the year. It varies because a considerable amount of rainfall is allowed to get into the sewers. It would vary little in towns where very little rainfall is allowed to get into the sewers, and where the water supply is pretty constant throughout the year. The variation in composition during the day and night is very important, and during the night, in many towns, the sewage is very little more than water.

Now as to the value—you may calculate the value of sewage in two ways. Thus you may calculate it approximately, from the number of persons who contribute to make it, and from the value that we have assigned to the refuse matters coming from each person during the year. We have assigned 8s. 4d. a year for these matters, but we will take the lowest value ever assigned to them, which is, that the annual excreta of a human being, taking an average of all ages, are worth 6s. 8d. a head. That value was assigned by Messrs. Lawes and Gilbert, and they have never been valued at less. So that, taking no other refuse at all, if you can get at the excretal refuse matters of a population of three millions, it ought to be worth £1,000,000 per annum, as far as that calculation goes.

But you may calculate the value, again, from the composition of sewage itself. And if you do that, you will find that the money value of the substances dissolved, say in 100 tons of average sewage, is about 15s., while the money value of the suspended matters is only about 2s. The value, then, of these constituents, is about 15s. for the dissolved matters, and 2s. for the suspended matters; that is to say, that 100 tons of average sewage are worth 17s., or about two pence a ton.

If you consider that you do not always get average sewage, or sewage of an average composition, and that very often the sewage is extremely diluted so that, instead of there being something like the dry weather average of sixty tons per head per annum, you often get 100, or even more, it is plain that we must not take so high a value as that I have just stated for it, and so it is usual to take a value of one penny per ton, instead of two pence. If then you take this sewage at a penny per ton, as containing on an average about four grains of ammonia in a gallon, as it does, or between five and six in 100,000 parts, as I said before, then you may consider that sewage is worth one farthing per ton for every grain of ammonia per gallon it contains.

And again, if you take the total amount of sewage of three millions of persons at an average dilution of about 80 tons per head per annum, and put it at the value of 1d. per ton, you will find it comes to almost exactly the same as the calculation made the other way, viz., something over £1,000,000.

Now what are we to do with this sewage which has the value which I have just assigned to it, that is to say, which has that value if you can get the manurial properties out of it? The general plan at present is to turn it into the rivers. This plan has arisen because the sewers we use were originally built for drains, and meant for drains, and therefore naturally discharged into the rivers, and it is no doubt from this circumstance that we have so many attempts to keep a certain proportion of the manurial refuse out of the sewers by means of midden closets, and pail closets, and earth closets and so on, and also with a view to the prevention of the fouling of the rivers. Well there are two kinds of evils that arise from the fouling of rivers, two especially, but there are plenty of others in addition. The first is that these riv-

ers, even when they are large ones, get to a certain extent blocked up by the sediment that is deposited from the sewers; this is the case even with the Thames. In the year 1867 it was pointed out that there was going on a formation of extensive shoals in the River Thames outside the main drainage outfalls near to Barking Creek and Crossness. These deposits were very extensive.

Near the southern outfalls for instance a depth of fully seven feet of deposit was found, and in fact it was going on to such an extent that it threatened to interfere seriously with the navigation. Plans can be seen which show that a narrowing of the bed of the stream had been going on even since this was pointed out in 1867. Besides that, it was also shown that the tide did not carry away the matters suspended in sewage. Experiments were made by Mr. Frank Foster first, and afterwards repeated by Mr. Bazalgette and Captain Burstal—which show that suspended matters, floating bodies, were carried down by the tide to a certain point, and then carried up again farther than the point at which they were originally thrown into the stream, and it is a fact that a certain amount of sewage deposit takes place above the outfalls into the River Thames. Now in small streams as well as in navigable rivers this is of course a very serious matter. That is the first thing. Then perhaps a less important matter, but still one of some importance, is that fish are killed in rivers into which sewage is turned. They are not killed by fresh sewage, but they are killed by the gases which are given off by the decomposing deposit at the bottom of the river, by sulphuretted hydrogen especially.

Then the next danger is the pollution of the drinking water of towns lower down on the rivers, and this has gone on to a very considerable extent, to such an extent that at last Londoners have found out what they are drinking, and all the towns on the River Thames have got injunctions to prevent them turning their sewage into the river. This comes to a climax when you have a case where a town actually turns its own sewage into a river at a particular place, and a mile further down takes out its water supply. That occurs in a town in England at the present moment.

If the towns are not to turn their sewage into a river, what can they do? You see the sewage contains suspended matters and dissolved matters, and both among the suspended matters and dissolved matters are substances that are injurious to health if drunk with water. You see also that the dissolved matters are considerably more valuable than the suspended matters, in the proportion of 15 to 2. But this was not always known, and so the first attempts at purifying the sewage consisted of simply straining it. The sewage was strained and the suspended matters were thus separated and were then sold as manure, or mixed with town ashes and sold for manure, and the somewhat clarified sewage was then allowed to escape into the stream. That is the practice carried on in a great many towns at the present time. The suspended matters are worth comparatively little, and you lose the best portion of the manurial matters. In the second place the purification of the stream is only partially effected, because the clarified sewage that runs into the stream putrifies after it gets there, and you get the stream fouled to a very considerable extent, so that that plan is evidently not sufficient.

Then come different chemical processes. The purification was attempted by various chemical processes, and it is still attempted to precipitate the valuable ingredients dissolved in the sewage as well as the suspended matters. Now there are plenty of ways in which you can clarify foul water, but you see at once that it is not so easy to precipitate those particular matters that are in solution in sewage, because you see in the first place that the most important constituent, or at any rate one of the most important constituents, the most important from its quantity at any rate, is the ammonia. You know perfectly well that you cannot precipitate salts of ammonia on a large scale at all from a dilute solution, and you will see, therefore, at once, that all attempts to precipitate the valuable matter of sewage are likely to fail, even from that cause alone. Then in the next place you have organic matter in solution. Now we do not know of any substance at present which can be used on

a large scale at any rate, that can be relied upon to precipitate organic matters in solution, especially organic matters in the state in which they are in sewage, viz.: in a state of very rapid decomposition, and these are the substances matter which are most dangerous, and which have to be separated, so that you will be prepared to find that most of the precipitation processes have failed. You will find a long description, and an excellent one, of most of these processes in the Second Report of the Sewage Commissioners, published in 1861, giving the results of many analyses. Several of these processes are capable of precipitating at any rate one important ingredient in sewage, and that is the phosphoric acid, an important ingredient which can be precipitated in several ways, and they also—some of them—precipitate some of the organic matters.

Now these are some of the more important precipitation processes brought before the public. In the first place there is the lime process which was practised at Tottenham and Leicester, and some other places, and which merely consisted in adding a certain proportion of milk of lime to the sewage. The result of this process was that no element of agricultural value that was in solution was precipitated by it except the phosphoric acid. The suspended matters were very fairly well removed from the sewage (that you can do perfectly well by straining), and sometimes the amount of organic matter in solution was increased, because some of the organic matter originally in suspension passed into a state of solution, which it always will do by mere agitation, and also the amount of ammonia contained in the sewage was increased, so that by that process, as well as by some others, the water discharged into the river sometimes contained actually more impure ingredients than the sewage contained in solution, some of the organic matters in suspension having passed into a state of solution. A fault of the lime process is that the precipitated matter remaining is alkaline, so that much of the ammonia it contains is given off, and the next thing is that it is nearly worthless.

The Rivers' Commissioners pronounce it "a conspicuous failure, whether as regards the manufacture of valuable manure or the purification of the offensive liquid." The next that I have to mention is a variety of the lime process, in which lime and per-salts of iron were mixed and used. This is a much better plan, because the per-salts of iron will fix the sulphuretted hydrogen and all the phosphoric acid. The fault of this plan is, that it does not precipitate anything else that the lime process did not, and its virtue is this, that it deodorizes the liquid and the precipitate. Salts of iron have been used alone, and they do without doubt deodorize the water, and precipitate the phosphates and the suspended matters, but they only delay the decomposition of it, and again they are too expensive.

Then several processes in which clay was a precipitating ingredient may be mentioned. In the first place, Holden's, in which sulphate of iron, lime, and coal dust, with some clay are used, and Anderson's, which is very much the same as Bird's, which consists in the addition to the sewage of crude sulphate of alumina. Stothert's consists of the addition of sulphate of alumina with sulphate of zinc and charcoal.

And, lastly, the celebrated A. B. C. process. The A. B. C. process was so called from the chief ingredients that were used, with the object of precipitating the sewage, namely, alum, blood and charcoal. You have all probably heard sufficiently about the A. B. C. process lately. You know the Company has attempted to purify some of the sewage of London, at Crossness, and no doubt you have heard that a combined report has been issued by the Engineer and the Chemist of the Metropolitan Board of Works, which report shows perfectly well that although the sewage was at any rate clarified, and although there was a certain amount of purification effected (we can't say exactly what amount, as in this report we have not the analysis of the original sewage); although that was the case, the manure produced was not worth more than twenty shillings a ton, while the cost of producing it was £6 6s. 4d.! Then there is a process known as Hille's process, which is chiefly a deodorizing process. A mixture of lime and tar, and chloride of magnesium is used; the precipitate is of very little value. Carbolates and sulphites of lime,

and magnesia, have also been proposed as precipitants which would also deodorize the sewage. At Carlisle, carbolic acid is used to deodorize the sewage.

There are two or three processes in which phosphates have been used. The idea of using phosphates to precipitate sewage was this,—that the precipitate produced by other substances, like lime and clay, which are useless as manures, will not sell, because it will not bear the cost of carriage; but if you add a substance which is itself a manure, and precipitate the suspended matters with it, then they would sell, and then you would get a manure that is worth carrying.

Now, the first phosphate process has been proposed over and over again. In England it goes by the name of Blyth's process, and the principle of it was this;—there is a salt of phosphoric acid (to wit, the phosphate of magnesium, ammonium and hydrogen, a triple phosphate), which salt is insoluble in water containing salts of ammonia, and it was thought that by adding a salt of magnesia and super-phosphate of lime, or super-phosphate of magnesia and lime water, to sewage, that a precipitate of this triple phosphate would take place. The result was that it was found to be the most expensive process ever adopted, and that a great proportion of the phosphate added went away in the effluent water. The salt in question is not at all insoluble in pure water. It is only insoluble in water containing an excess of ammonia; so that the condition for the success of this experiment was that the water turned into the river was rich in ammonia — an obvious condition for failure of the experiment—and the result was the loss of a great amount of the substances added. That process has failed over and over again.

Then we have a phosphate process patented by Messrs. Forbes and Price. In this process an insoluble phosphate of alumina in large quantities is used, and it is rendered soluble by being mixed with strong hydro-chloric acid. This is mixed with sewage, lime water then is added, and the result is that the suspended matters are carried down very completely, and the sewage is left very clear. All offensiveness is entirely taken away; the effluent water passes off containing all the ammonia that the sewage contained before, and at any rate the greater portion of the organic matter in solution. This process, therefore, could only be used as a preliminary process to some other treatment. I will not say any more about that.

Then recently another phosphate process has come forward, called Whitthread's. That process has been reported on by the Committee of the British Association appointed for the consideration of the treatment and utilization of sewage, and that process is the only precipitating process with respect to which it has ever been said that it does precipitate most of the organic matter that is in solution. It precipitates all the suspended matters, and so far as the preliminary experiments, which were carried on under the supervision of the Committee of the British Association,—as far as those preliminary experiments go, this process depends upon the use of a substance known as di-calcic phosphate, a particular form of phosphate of lime, which seems to have the property of carrying down organic matters in solution. The deodorization is also complete. It does not in any way remove the ammonia in solution, and it remains to be seen whether that process, or indeed any other process, is capable on the large scale of so removing the organic matters in solution that the liquid may at any rate be harmless after it is thrown away.

Lastly, I have to mention to you General Scott's process. General Scott's process consists in mixing the sewage with a certain amount of lime and of clay. It has been reported on by the Rivers' Pollution Commissioners and by the British Association Sewage Committee. About 10 cwt. of lime and 8 cwt. of clay are added to 400,000 gallons of sewage. This mixture of lime and clay is added in considerably greater proportions than the precipitants are added under the other processes. With the others you add as little as possible. With General Scott's process you add a great deal. Well, this mixture is added to the sewage in the sewers before it gets to the tanks, and the result is that the sewage is entirely deodorized, and as soon as it arrives at the precipitating tanks and is allowed to settle, the whole of the suspended matters, including the

lime and clay which have been added, are deposited at the bottom of the tanks. This deposit is run out in a semi-liquid condition as soon as there is enough of it. It is then dried, or it may be compressed by what is known as Needham and Kite's Press. Needham and Kite's Press is a press which has a number of canvas bags in it, into which bags this mud is run. They are then pressed together by a hydraulic press. A certain portion of water is thus squeezed out of the mud, leaving it in a comparatively dry state. It is then taken up in lumps, dried by heat if necessary, and placed in a kiln. A fire is lighted below it with a small quantity of coal, and it burns.

"The area is laid out in square beds intersected with roads and paths, along which are constructed the main carriers which receive the sewage from the outfall sewer and distribute it over the beds." As soon as it is once set alight there is no necessity to put any more coals in the kiln. The sewage deposit with the clay and lime is supplied from the top of the kiln, and it is gradually taken out as it is burnt, through an opening in the bottom, and no more coal is required. There is sufficient organic matter in the deposit for it to go on burning, when once well lighted, for any length of time. The result is the production of a cement, and an excellent cement. This cement can be made of different qualities, and it certainly answers perfectly well as a cement, and the process causes no offence.

The result on the sewage is that it is clarified, and the phosphoric acid contained in solution is precipitated, so that this cement contains phosphoric acid. The ammoniacal salts are left in solution, and the organic matters in solution are not touched by the process, or rather they may occasionally be increased from some of those matters in suspension passing into a state of solution. The cement prepared can be used as ordinary cement; or it has been suggested by General Scott that in places where lime is already used as a manure, it would be considerably better to use this sewage lime, after it has been calcined, on account of the proportion of phosphoric acid in it. It is a process, then, that does not at all pretend to purify the sewage; it merely pretends to afford a means of dealing with the suspended matters of the sewage, and to leave it in a condition in which it is better fitted for treatment afterwards.

We pass on now to the remaining methods for the treatment of sewage, which depend upon the filtration of it through soil. I have described to you the effects of the filtration of foul water through gravel and sand and charcoal. You may say this can be done for water containing a small amount of impurity, but can it be done for water containing a large amount of organic matters both in suspension and solution, as is the case with sewage? Now, filtration may be of two kinds; at any rate there are two principal kinds, downward and upward. You may either pour the water on to the surface of the filter and allow it to pass through, or you may conduct the water underneath the filter, and let it rise up through the filtering material. By the first process, which is known as downward filtration, sewage can be satisfactorily purified on one condition, namely, that the filtration shall be intermittent. I told you how a filter purifies, and you will see at once that this is a necessary condition for the purification of sewage. If you have sewage falling on a filter bed and passing through it to drains below, the organic matters in that sewage are only oxydized, if there is air in the filter; and there cannot be air in the filter unless your process is intermittent. But if your process is intermittent, when you stop pouring sewage on to the filter bed, the remaining water trickles down into the drain below, and so fills your filter with air. You must have an intermittent process.

That shows you again why upward filtration is not capable of purifying sewage. Supposing you have water admitted underneath the filter, and that it is so constructed that it can rise up to the surface of the bed and flow off it, your filter bed is always charged with water. Upward filtration then does not afford the means of aërating the water. By intermittent downward filtration we have a means—as pointed out by the Rivers' Pollution Commissioners (1868)—a means of satisfactorily purifying sewage.

Experiments conducted by filtering London sewage through 15 feet of sand

showed in the first place that "the process of *upward* filtration through sand is insufficient in the purification of sewage from soluble offensive matters ; . . . . on no occasion was the effluent water in a condition fit to be admitted into running streams," but that the "process of intermittent *downward* filtration through either sand or a mixture of chalk and sand effects a very satisfactory purification of sewage when the sewage treated amounts to 5.6 gallons per cubic yard of filtering material in 24 hours ; but that the purification becomes uncertain and unsatisfactory when the rate of filtration is doubled, that is when the sewage treated amounts to 11.2 gallons per cubic yard in 24 hours." And so on. And then the amount of purification is given, and the value of different soils as purifying agents. Now, filtration through charcoal has been used in one process, the process known as Messrs. Weare's process ; the process has been used in the filtration of the sewage of the workhouse at Stoke-upon-Trent. One would have expected, if the experiment had been conducted properly, that it would have been a success. However, all the sewage of that particular place was exceedingly strong, and although it was purified to a considerable extent by Weare's process, it is not reported favorably on in the report of the British Association Committee, and it has not been employed on a larger scale. Then intermittent downward filtration through soil has been employed as a means of purifying sewage on a very large scale at Merthyr Tydfil by Mr. Bailey Denton, and this has been reported on by the Rivers' Pollution Commissioners and also by the British Association Committee.

"Merthyr-Tydfil contains a population of 50,000—I am now coating from the proof sheets of last year's report of the British Association Committee—but according to information supplied to the Committee, the excretal refuse of not more than two-fifths of this number is discharged into the sewers, although the slops and other liquid refuse from a further like number (20,000) is stated to be admitted. It is not surprising, therefore, that the sewage is, as afterwards appears, weak." "An area of about 20 acres has, under the supervision of a member of the Committee, been converted into a filter bed for the practice of the system of downward filtration originated by the Rivers' Pollution Commissioners, as above described." "The soil of this area consists of a deep bed of gravel (probably the former bed of the River Taff, which is embanked up on the east side and is raised above the valley) composed of rounded pebbles of the Old Red Sandstone and Coal-measure formations, interspersed with some loam and beds of sand, forming an extremely porous deposit, and having a vegetable mould on the surface."

"The land has been pipe-drained at a depth of less than 7 feet, and the pipes are concentrated at the lowest corner, where the effluent water is discharged into the open drain which leads to the river Taff at some distance down the valley."

"The sewage before entering the farm is screened through a bed of 'slag' which arrests the coarser matters. It is applied to the land intermittently, for the area being divided into 4 plots or beds, it is turned on each one for 6 hours at a time, leaving an interval of 18 hours for rest and aëration of the soil." So that you see the right principal is carried out there. When the Rivers' Pollution Commissioners reported on intermittent downward filtration through soil, they said that it could be used to purify sewage. They also said, and it was so thought, that the sewage would be entirely wasted ; that the greater amount of it is wasted, as you will directly see ; but that it need not be entirely wasted we can see from these experiments at Merthyr-Tydfil, where large crops are grown upon the limited area.

"The surface of the land was cultivated to a depth from 16 to 18 inches, and laid up in ridges, in order that the sewage might run down the furrows, while the ridges were planted with cabbages and other vegetables."

Well now, this process has been carried out on a large scale, and it has been examined with the following results by the "Rivers' Pollution Commissioners," and also by the "British Association Committee," and both sets of examiners have come to the conclusion that the purification is satisfactory. I am not going to give you the numbers,

but I am just going to give you one or two facts about it. In the first place, when you look at the analysis of the sewage of a filter bed like this, you always have to take into consideration the possibility of dilution of the sewage with subsoil water, and in this place the dilution of the sewage with water from the river Taff is considerable. In the summer it was diluted with certainly more than an equal volume of subsoil water, and the gaugings in the winter showed that each gallon of sewage had become mixed with about 2 gallons of subsoil water. When this is allowed for, if you compare the results of the analysis of the effluent water with that of the analysis of the sewage, you find first that the suspended matters are all removed. Then with regard to the dissolved matters, the nitrogen, instead of appearing as it does in sewage as ammonia and organic nitrogen, appears as nitric acid ; it has very nearly all been oxydized,—a result that we get from purification of drinking waters by filtration ; but the importance and interest of the matter is, that after making allowances for dilution with subsoil water, the total amount of nitrogen in the effluent water is almost exactly the same as the total amount of nitrogen in the dissolved matters in the sewage, although in a different condition ; that is to say, that the nitogen retained by the land is almost exactly equivalent to the amount of nitrogen in the suspended matters. The effluent water, I may tell you, was so pure, both in the winter and in the summer, that in the winter nearly all the nitrogen in it was in the form of nitrates and nitrites, and in the summer $\frac{4}{5}$ths of it was in the same oxydized and harmless condition.

We have now to consider the subject of sewage irrigation. I have shown you that by filtration through the soil in a particular manner, sewage could be satisfactorily purified ; could be purified, in fact, so that the water which had passed through a filter of sand, gravel, or soil, was, practically speaking, drinking water. It is perfectly plain, therefore, that if you enlarge the area of your filter, and pass the sewage through a certain depth of soil, you can in that way, even without the action of plants, satisfactorily purify sewage. But as irrigation farms existed before intermittent downward filtration was thought of, it is neccessary for us to consider whether it is sufficient merely to turn the sewage on to unprepared land—whether it is sufficient that this should be done without making it a necessity that the sewage should pass through the soil.

There are now, at any rate, two classes of irrigationists. One set tells you that an irrigation farm is nothing in the world but a very large filter ; that it is absolutely necessary for the purification of the sewage at all times of the year that the sewage should pass through the land. I mean to say they will tell you that at certain times of the year, at any rate, if the sewage does not pass through the land, it will not be satisfactorily purified, and that there is danger of its not being satisfactorily purified at any time.

Others again say that it is not necessary that the sewage should pass through the soil into drains, and that it is not even necessary that the land should be drained in many cases at any rate. In the first place, there can be no doubt that upon almost all impervious soils, sewage can be purified by surface action to a very large extent indeed. At some of our sewage farms they work upon this principal. The sewage does not pass through the soil at all. On the soil plants are growing, and they take up the organic matters, ammonia, &c., from the sewage ; and the water which passes off, the overflow, is remarkably pure. But it will remain for us to consider bye and bye, whether, when plant action is least, this would be the case, whether in such cases the effluent water should not be left in an impure condition. Well, now you have sewage brought on to a farm, if you are able to do it, by gravitation, if not, by pumping. On the farm tanks are constructed ; as a rule, two tanks, the one being merely to be used while the other is cleaned out. Tanks are considered by many persons as not specially necessary, but they are so, both for the separation and collection of the grosser suspended matters and also for storing the night sewage. The sewage is run out from one of the tanks neither from the top nor from the bottom. At the bottom the sediment is allowed to deposit. At the top the scum accumulates, covers over the surface of

the liquid, and to a great extent diminishes the offensive ordor. The sewage is allowed to run out between the scum at the top and the sediment at the bottom. One of the simplest ways of effecting this is by means of a kind of floodgate (such as one you may see at Brenton's farm, near Romford), made of pieces of board slid down one over another; rings are fixed to the sides of these boards, so that one or more of them may at any time be lifted a little by means of a rod with hooks at the end, and then the sewage will run out through the gap made; the lower part of the flood gate keeping back the sludge, and the upper boards keeping back the scum. The sewage flows either directly into the *carriers*, or when it has to be pumped, into the pumping well.

To take the sewage on to the land from the tanks, you may use concrete carriers, as they are the easiest made, and the cheapest. If you want the work to look particularly well, you can use brick-work, or earthenware, at the Tunbridge Wells.

If the carriers have to be lifted above the ground, as where there is a pumping station on the farm itself, they are best made of sheet iron, supported on wooden tressels. They must have simple taps which can be opened by merely taking out a plug.

These carriers run in directions which depend upon the slope of the land.

In the first place, I may tell you that the best sort of land to irrigate is flat land—quite flat—and then that which gently slopes. The main carriers are to run at right angles to the slopes of the land. They are carried under the roads by means of inverted syphons, and then the land is divided at right angles to these carriers into parallel beds.

I am now describing to you the plan which I believe to be the best.

The land is arranged in ridges and furrows, the crests of the ridges running at right angles of the main carriers and down the middle of each bed, so that each bed slopes slightly from the middle towards each side. At Brenton's Farm, where you can see the plan at work, the beds are 30 feet across. Along the top of the ridge there is run a minor carrier. This is merely a groove made along the crest of the ridge by a plough. The taps on the main carriers are just opposite to the beginning of these minor carriers, and the sewage can be let out of the taps and allowed to run along the minor carriers. When the minor carrier is full the sewage overflows and runs over the bed down each side into the furrows between it and the adjacent bed. It may be allowed to run into the minor carrier as long as no pounding occurs in the furrow. That is the "ridge and furrow plan."

There is another system called the "catch-water system." In that plan the sewage is taken in carriers along contour lines. The carrier along the high contour line is filled, and the sewage stopped at a particular place; it overflows and runs down the slope of the land into the carrier below. You can see that at work at many irrigation farms.

There is a variety of that called the "pane and gutter" system. I do not know that I need explain it in detail. The land is divided into pieces or "panes," running down the slope, and at right angles to the main carriers, and the sewage is run over the surface of these "panes" from the higher carriers into the lower ones.

There has been for a long time at Milan a plan of simply flooding the whole of the land, but in this way marshes are produced. The first obvious disadvantage of the catch-water and pane and gutter plans is that some land gets much more than the rest; because all the sewage that flows over the lowest level of a bed must pass over the whole bed from the top. If the land below gets enough, the land above gets too much, besides the fact that the lower beds get all the water that flows off the upper ones. On the other hand, with the "ridge-and-furrow" system I described before, you can just allow each particular bit exactly the amount it wants.

A boy goes along the carrier, turning on and off the taps as they are wanted, and a man walks up and down the ridges and stops the sewage at intervals, so that it overflows the minor carrier on each side and runs over the bed.

Any channels that convey sewage may be open. There is no reason whatever for covering them over. The loss of

ammonia, &c., from the sewage is perfectly inappreciable even after a passage for a very long time through the open air, as proved by the experiments of the Rivers' Pollution Commissioners. You know already that by passing it through soil sewage can be purified. Now, a few words about passing it over the surface of the soil. The Committee of the British Association have made experiments upon this very point; and I have comparisons of the results of the purification of sewage during very severe winter weather at some different farms. Now the first of these is Beddington Farm, Croydon. Here the analysis showed "that the nitrogen that is lost on this farm is lost for the most part in the form in which it came into the land, and that mere surface action (which is relied on here), is not sufficient to cause the oxydization of the ammonia and organic matters contained in the sewage. At the same time the purification effected was certainly very considerable."

Then again, the effluent water at the Norwood farm during the severe frost, was, practically speaking, sewage containing nearly half the amount of the ammonia that the sewage put on the farm did. It contained very little nitrogen in the form of nitrates. You know I told you that the main action of a filter was the conversion of ammonia and the nitrogen contained in organic matters into nitric acid. So that the amount of nitric acid in effluent water is a test of the oxydizing action of the filter. At the same time the analysis of the effluent water at Brenton's Farm, Romford, showed that the purification was very satisfactory indeed, for the effluent water only contained a very small quantity of actual ammonia, that is to say, about 0.14 parts in 100,000, as against 5.6 contained in the sewage, and of albuminoid ammonia only 0.059 parts remained out of 0.524 in the sewage, while the effluent water contained no less than 1.2 parts of nitrogen in the form of nitrates and nitrites.

In winter, when little action of vegetation is going on, mere passage *over* the soil will not purifiy sewage satisfactorily. The effluent water which goes off the land, is, to all intents and purposes sewage. On the other hand, there is a perfectly clear proof, that during winter if you pass the sewage *through* the soil, as at Brenton's Farm, purification goes on just the same as at any other time of the year when vegetation is growing.

Even during the summer there is a risk that the sewage may not be satisfactorily purified where the catch-water principal is adopted. This happened at Reigate, where the sewage was passed over one field and then over another, and the effluent water that came off the lower part of the second field was actualy more impure in several ways than that which came on to it from the first field; that is to say, that this second field was to a certain depth so absolutely saturated with sewage, that the water, or sewage, or whatever you like to call it that came from the first field actually became more impure the further it went. It was in fact made stronger by the amount of evaporation which went on, and is another conclusive proof that surface action is not sufficient.

These results seem to me decisive in favor of the construction of irrigation farms as large filters. Then we come to the practical point—that it is therefore necessary that they should be drained.

On this head the British Association Committee express the following opinion:—

"It may seem almost superfluous for the Committee after so many years of general experience throughout the country, to argue in favor of the subsoil drainage of naturally heavy or naturally wet land, with impervious subsoil, for the purposes of ordinary agriculture; but some persons have strongly and repeatedly called in question the necessity of draining land when irrigated with sewage; and the two farms at Tunbridge Wells, to a great extent, and more especially the Reigate farm at Earlswood, have been actually laid out for sewage irrigation on what may be called the 'saturation' principal; so that it appears to the Committee desirable to call attention to the fact, that if drainage is necessary where no water is artificially applied to the soil, it cannot be *less* necessary after an addition to the rainfall of 100 or 200 per cent. But a comparison of the analysis of different samples of effluent waters which have been taken by the Committee from open ditches into which effluent water was

overflowing off saturated land, and from subsoil drains into which effluent water was intermittently percolating through several feet of soil, suggests grave doubts whether effluent water ought ever to be permitted to escape before it has percolated through the soil."

There are some other plans that have been suggested for the distribution of sewage,—one is by means of the ordinary agricultural drainage. That is obviously perfectly absurd. It is impossible to imagine that sewage could be purified by turning it into agricultural drains below the roots of the plants. Another plan, very much advocated, is to conduct it in pipes just out of reach of the plow, and then to distribute it over the land and plants by means of hose and jet. The thing that is immensely against this, is the expense from the enormous amount of labor; also, that if sewage farms are not to be (and they certainly need not be) nuisances, it is not by squirting the sewage about that we shall attain that object. As to the flood plan which is pursued at Milan, I do not think I need say more than two words about it. It is perfectly plain that we don't want to make sewage marshes, at any rate here. There, at Milan, the water meadows cause ordinary marsh fevers. They do not cause any of the diseases that it was expected sewage farms would cause; they do not favor in any way such diseases as cholera or typhoid fever, which diseases are spread to a very great extent by means of the intestinal evacuations of those suffering from them. I think perhaps as I have gone into the question of public health, I may just say the word or two that I have to say upon that point. I do not think you would find a single case definitely proved against sewage farms — badly conducted as many of them are—where they have been injurious to health, except in this way. If water that contains poison from sewage that has flown over the land and that has not percolated through it, if that water is drunk, it is very likely poisonous. That has been the case once or twice. The farms have not caused by noxious emanations any injury to the health of neighborhoods where they have been placed. I do not think there is the slightest evidence to show that. Then about the water that passes from them. It is said that in certain cases it has poisoned the wells in the neighborhood. There is no evidence of anything of the sort. Where these cases have been inquired into, it has been found that the wells have not been poisoned from the sewage farms, but by foul matters from perfectly different sources. It is true that in one or two cases in which the water which had passed over the sewage-meadows was drunk, a certain number of people got typhoid fever. In sewage-meadows where surface action is relied upon there is considerable danger that the overflow of the channels should be mistaken for fresh water. You understand that when a sewage farm is a large filter, and the effluent water is collected in subsoil drains, this water is perfectly fit to drink. I can tell you of a sewage farm where it is usually drunk by the workmen. There is a well on that particular farm, the water of which is excellent, and there is no reason why it should not be so. Our own drinking water in London, and in most large towns, has got purified from all kinds of impurities by passage through gravel and sand. Dr. Angus Smith tells us that we could not drink rain-water if collected from the clouds anywhere near to large towns; it would be too foul, and would have to be passed through soil in order to be purified.

Well now, the last point that I have to notice in connexion with the public health is the alleged danger from the spread of entozoic diseases by means of sewage irrigation. Dr. Cobbold, the great authority upon entozoa, thinks that if sewage farms are spread much over the land, we shall have more of entozoic diseases, and that deaths from them will become much more frequent, and he even suggested that an entozon which is very fatal in some parts of Northern Africa (the Bilharzia hæmatobia) might become prevalent in this country. But that entozoon is, in the first place, prevalent in those countries especially during the hot seasons. In the second place, we know next to nothing about the different stages it goes through, during which it no doubt inhabits different animals (snails, &c.); and lastly, Dr. Cobbold himself has shown that the larvæ of this parasite

cannot live in impure water. So we may dismiss that at once. Then with regard to ordinary entozoa. In the first place, there is no sort of evidence whatever to show that they have been spread in cattle at farms where irrigation has been going on for 200 years. Professor Christion has distinctly stated that he has never been able to trace entozoic disease to the Craigentinny meadows near Edinburgh, neither is there evidence that this has been done anywhere else. It is very easy to say that the eggs of the entozoa are in the sewage when it is carried on to the land, and that the larvæ will be developed as soon as the plants are eaten by animals. In the first place, you must know that it is necessary that these eggs should be living and fertilized too, and they have the smallest chance of living that anything can possibly have by the time they get with the sewage to the land, for they have a considerable distance to go before they get to the farm; they are tossed about in an alkaline liquid, their natural habitat being acid excretions; they are turned on to the ground and taken down into the soil with the water. However, to prevent any apprehension on this score the simplest thing is to have the grass cut and carried to the stalls, and not to graze animals upon it. Many of the best irrigationists insist upon this.

Some investigations of this matter were made by the British Association Committee.

"An ox which had been fed for the previous 22 months entirely on sewage grown produce" was slaughtered and carcass examined by Dr. Cobbold, Professor Marshall and myself; no trace of any entozoic disease was found in it, although most carefully looked for. Dr. Cobbold suggests several reasons for this result, and one of these is the freedom of the sewage farm from snails and insects, in the bodies of which many of these entozoa go through different stages of their existence; it seems, therefore, that the sewage kills those creatures which are necessary for the existence of these entozoa in their different stages. Dr. Cobbold also examined under the microscope portions of "flaky vegetable tufts," collected from the sides of the minor sewage carriers, and found that, although they contained animal as well as vegetable life, they contained "no ova of any true entozoon." So that you see that as far as we have got positive evidence it is entirely against the theory that entozoic diseases are spread in cattle, and from them down, by means of sewage irrigation.

Now a few words about the crops. The most suitable crop for sewage is Italian rye grass. This plant will take up a very large amount of sewage. If you read the reports of the sewage of Towns Commissioners you will find the results of experiments upon the amounts of meadow grass grown with different quantities of sewage.

There was an average increase of about 4 tons of grass for each thousand tons of sewage applied per acre: the maximum amount of the latter being about 9,000 tons per acre per annum. The largest amount was about 33 tons of green grass per acre in one year, and 37 tons in another. Some of the land was not supplied with sewage at all; other parts with 3,000, 6,000, and 9,000 tons per acre per annum. The increase of produce was much greater with the first 3,000 tons of sewage than it was when the amount was increased from 3,000 to 6,000 tons, and more from 3,000 to 6,000 than from 6,000 to 9,000. So that the increased amount of sewage did not produce a proportionately increased amount of produce. The increase of produce per 1,000 tons of sewage was when 3,000 tons were applied about 5 tons of green grass, when 6,000 tons were applied 4 tons 2½ cwt., and when 9,000 tons were applied 3 tons 3¼ cwt. And the results given by Italian rye grass showed about the same increase of produce. It was also found that an earlier cut of green grass could be obtained by means of sewage irrigation.

Experiments were made about the quality as well as about the quantity, and it was found that the grass contained a smaller actual amount of dry solid matters when grown with sewage, but was richer in nitrogen, and was, in fact, more readily assimilable — more milk could be got from it.

The main result of irrigation farms must be the feeding of cattle and the production of milk. The sewage is turned into Italian rye grass, and is returned to the town from which the sew-

age has come as milk, butter, cheese and beef.

Then, if Italian rye grass can be grown, every grass and almost anything else can as well. You will see that denied even to this day, in spite of the fact that almost everything else has been grown with it. These different plants can be grown upon land which is absolutely and perfectly valueless in an agricultural point of view without sewage, even upon blowing sea sand, and you can see in many parts of England excellent crops now growing by means of the use of this rich manure. Cereals can be grown perfectly well with considerable returns. In 1868 and 1869 (at Lodge Farm, Barking), wheat, winter oats, rye and cabbages were grown. In 1868 wheat was grown on a slope of shingle. It had two dressings of sewage equal to 450 or 500 tons in all. The results were 5 qr. 3 bush., as against 3 qr. 5 bush. without sewage, with 4½ loads of straw, as against 3 to the acre. The winter oats yielded 8 qr. of corn, with three loads of straw to the acre. Among other vegetables must be especially mentioned beet-root. From experiments which have been made there seems very little doubt that beet-root can be grown for the production of sugar in almost any quantity. Professor Voelcker has analyzed some of the beet-roots grown on sewage, and they gave 13.19 per cent. of sugar, while the beet-roots from Holland, Suffolk and Scotland, only gave from nine to ten per cent. of it at the outside.

Well, now a word or two about the times when you don't want sewage on the land. There may be times when you don't want it at all—times when the sewage is too dilute, and the land is very wet, as during heavy floods ; and this is a very strong argument for keeping the drainage water, properly so called, out of the sewage, the utilization of sewage is thereby rendered very much easier. The best dilution for sewage is when it represents 25 to 30 gallons per head of the population. If you keep the drainage water as much as possible separate, you can always turn it into it as a diluent when more water is wanted.

The amount of sewage required per acre varies much with different crops and with different soils, but it is usually considered that the sewage of from 35 to 40 persons is sufficient per acre on the average, although in many instances much more than that is applied.

On every sewage farm there should be a piece of fallow land to be used as a filter, not with the view of any great return, but simply with a view to purifying the sewage whether the crop on that particular land happens to want it or not, when it is not wanted on any other part of the farm.

You see, then, that intermittent downward filtration through soil and irrigation farming, with passage of the liquid through the soil, are the only means at present known for purifying sewage, and these may be well continued, with some deodorizing process, which will prevent the sludge in the tanks from being offensive, except where the tanks are in the open country, when this is hardly necessary ; and you see also that these processes in themselves are in no way injurious to the health of the neighborhood where they are carried on ; one of them, irrigation farming, with the condition mentioned above, also affords the only method known by which the valuable manurial ingredients dissolved in sewage can be utilized—can be turned into wholesome food for man and beast; and it is therefore for you in those parts of the world in which you may be stationed, and where you will have to advise on such matters, to use your influence in obtaining the adoption of the water-carriage system, as before described, in connection with a properly carried out plan of irrigation farming.

The removal of waste matters is the first thing to consider, their utilization the second ; where you have both, there you are best able to compete with disease and death.

Extension of Telegraphy in France.—The engineers of the river service of France have been instructed to draw up for the principal navigable watercourses of France plans for the establishment of a telegraphic service similar to that which has just been inaugurated on the Seine. At all the sluices and flood-gates on the river telegraph poles have been set up, and the service of the river is much facilitated by the quick transmission of the state of level.

TOUGHENED GLASS.

From "The Engineer."

SEVERAL months have elapsed since wonder was first excited by the announcement that something approaching in properties to the mythical malleable glass of antiquity had been discovered. It was no new material that was brought forward, and scarcely even a new process, but something very like the old and well-known process, as applied to steel, of tempering it in oil. It was alleged that common glass, or to endeavor to extract from the accounts something a little more exact, that flint glass containing lead, from which the thin plates on which ice is served are blown, or plate-glass containing no lead, could be made greatly more resistant by heating either of these to some known high temperature and plunging the glass into some mixture of oil with tarry matter, this mixture being also heated to some known temperature; and it was added that the air of the apartment in which the operation was conducted must be at some fixed temperature also. But these temperatures, though alleged to be essential to the success of the process, were most unsatisfactorily kept secret, and we were called upon to admire the result of an imperfectly divulged process as enabling the glass treated by to become far more resistant to impact by the recital of such very crude experiments as those recorded by us in April last, in which a 6in. square plate of glass set loosely in a wooden frame like a schoolboy's slate was broken by the fall on to its face of a 2 oz. brass weight from a height of 2ft., whilst it required an iron weight of 8 oz. falling from a height of 6ft. to break a similar, but rather thinner, piece of the same glass which had been subjected to M. La Bastie's process. The difference between the work done in both cases is about as one to twelve, and this really does not represent fully the difference of resisting power in the two cases, because, as has been demonstrated by Dr. Young and others, the power of impulse to produce fracture in brittle bodies increases with the velocities of impact independently of the work lodged in the impelled body, and also with the rigidity of the striking body, the iron weight being here more rigid than a brass one. For all this the experiment is an extremely unsatisfactory one. Why should the plates of glass be set in a wooden frame at all in place of being simply laid upon a flat rigid surface with a square aperture through it nearly the size of the plate? The slightest inequality of bearing or of greater or less looseness wherewith the glass was held in the wooden frame might so materially affect the result as to deprive the experiment of all scientific value, though we may admit it as demonstrative of a great difference in resistance to impact. We are told also that this process greatly increases the resistance of a strip of glass to a steady tensile force; it is added also that if a piece of glass which has been subjected to La Bastie's process be broken by impulse it is not fractured in certain irregular lines radiating from the point of impact, but that the whole piece breaks up into small fragments like those into which a Rupert's drop breaks explosively when its tail is pinched off. Furthermore, it appears by the account of experiments made officially by agents of M. de La Bastie, before glass manufacturers at Pittsburgh, U. S., which we copied from the *Pittsburgh Herald* in a recent impression, that when once the slightest abrasion is made "upon the surface of this glass the entire piece was reduced to powder." If we are to rely upon the facts as stated, the La Bastie glass is as completely in the condition of a Rupert's drop as it might be, if in place of being tempered in oil and tar, it had been dropped liquid into water. Now, if this be so, if in accordance with the somewhat crude speculations which, without anything of experimental support, have been hazarded to account for the changed condition of the glass, we admit for the moment that its exterior and interior layers are held in a state of mutual constraint by unequal contraction, how is it possible that glass in such a state should offer a greater resistance to a steady tensile strain than the same glass, all of whose particles were in a

state of repose, and free from mutual constraints. Is the fact certain that there is any such increase of ultimate tensile resistance conferred by this process? If it really be so, it would only add to the inexplicable character alleged as to other of the results of this process; but for anything that has as yet come to our knowledge, this alleged increase of ultimate tensile resistance may rest merely upon delusive experiment.

Every physicist is aware of the almost insuperable difficulties which attend all attempts to determine, experimentally, the tensile resistance of very rigid bodies. The discrepancy between recorded experiments made by competent physicists upon bodies far less rigid than glass, such as bell metal, speculum metal, &c., amply prove this ; and still more so do the results obtained by Messrs. Fairbairn and Tate, upon several species of glass itself. These last indicated a resistance to compression as compared with that to tension so enormously exceeding those of any other known bodies, as to warrant the conclusion that while the experiments on compression made upon short cylinders or prisms may be nearly correct, those recorded for the resistance to tension are greatly below the truth, arising from the almost certain departure, of the line of pull from the axis of the piece. It seems possible, therefore, that the alleged greater tenacity of the La Bastie glass may be a result of its possessing within certain very narrow limits greater flexibility than ordinary glass, so that when subjected to a tensile strain, it is enabled to slightly alter its form, so as more nearly to admit of the pull passing through the axis of the piece. We would not be understood, however, as offering any opinion on this point, but merely suggesting it as one of those to be borne in view in the further experiments that must be conducted before even the most primary facts of this curious subject can be said to be established. In the account to which we have above referred, we find some further statements which appear to us inexplicable, if not contradictory ; it is alleged that La Bastie's process was anticipated as far back as the year 1822, at the works of Bakewell, Pears, and Co., and that for the purpose of rendering ordinary glass—flint glass we must presume—less liable to fracture when undergoing the process of ornamental cutting by the glass grinder's wheel, it was previously boiled in fish oil, which it is alleged prevented further annoyance by fracture during the grinding.

Now, as the process of glass grinding or cutting is, until the stage for polishing be reached, neither more nor less than one of abrasion upon a grit stone or a lead lap coated with emery, and as it is stated that the slightest abrasion of the surface causes the La Bastie glass to fly to pieces by a scratch, so it is extremely difficult to see why an exactly opposite result to that recorded should not have taken place by this boiling in oil. Besides the great need of corroboration thus suggested, this alleged American process is no anticipation at all of La Bastie's ; the two processes are entirely distinct, and we certainly should not be prepared by any known analogy to believe that cold glass, we presume already annealed in the ordinary way in the "leer," should have its physicial properties altered as described by being kept immersed for any length of time, however great, in fish oil, which boils at a temperature between the melting point of tin and that of lead.

In a lecture delivered at a meeting of the Society for the Encouragement of Arts and Manufacturers on the 2nd of June last, we find some other statements which seem more or less irreconcileable with each other. It is there admitted that if only a corner be broken off by a blow from a plate of this glass the whole plate flies into fragments. It is also admitted that plates of this glass cannot be cut by the glazier's diamond. Not indeed, we must infer, because the surface of the glass be increased in hardness to such an extent as to equal that of the diamond, but that the stroke made by the diamond does not produce a straight and even fracture as in ordinary glass, but one jagged and irregular, and which may diverge more or less from the path that the diamond has described; yet we are informed that this same glass may be engraved upon by fluoric acid, which we should not be prepared to doubt, and also may be engraved by Tilghman's sand blast process, a fact as to which we must entertain much doubt in view of the difficulty of producing a

straight diamond cut, and of the statement that the breaking off of a corner, or a surface abrasion, breaks up the whole piece. Brewster, indeed, found that a considerable portion of the bulbous end of a Rupert's drop might be slowly and carefully ground off upon the lapidary's wheel without that always producing its explosion, provided the surface being ground off was always normal to the axis of the drop, but this is a very different thing from the rough vibratory grinding produced by the ordinary work of the glass cutter. Amongst the points left in obscurity as to the La Bastie process is one which may be far from immaterial. Is it necessary that the glass taken from the glass-house pot, formed by blowing or otherwise and annealed, must be let to cool and then heated again up to redness, or thereabouts, before being quenched in the hydrocarbon oil bath; or, is the result equally attained by taking the glass directly it has become stiffened from the glass blower's pipe or mould, and while still at the requisite high temperature, and at once quenching it in the bath without any intermediate process of annealing and cooling? No experiment nor sufficient information has been recorded as to this, but from some facts stated in the discussion following the lecture to which we have above alluded, it may be inferred that the same effects would be produced if the temperature at the moment of immersion be the same whether the glass, without being allowed to cool on blowing, were at once dropped into the hydrocarbon bath, or whether, having been let cool, it were again slowly heated up to a sufficient temperature and then passed into the bath. The real point of practical difficulty in either case seems to be that the glass when dropped into the bath must be at a temperature so nearly approaching that of its fusion as to be soft and viscous, and that if it be let to cool but a little below this point the effect of the bath is partial and incomplete. Whatever happens as a result of the La Bastie process is something obviously different from that of annealing as heretofore understood, and when closely examined almost all analogy between this process and the tempering of hardened steel in oil disappears.

The steel has been already heated to a temperature at which, if quenched in water, it would become intensely hard, and in that condition, if fractured, breaks with a fracture approaching the vitreous in its character. The heat of the piece is carried off in the water with immense rapidity by the generation of steam, which is condensed as rapidly as it is formed in the remoter parts of the fluid, aided also by the rapid currents induced in the latter by difference of temperature, and also by rapid influx of cold water. Heated to the same temperature and quenched in oil, however, the steel is cooled by convection and conduction, and in a liquid of probably low conductivity and of so much viscidity as to retard circulatory currents; it is, therefore, cooled rapidly indeed as compared with the time of a like amount of cooling in still air, but by no means suddenly. The result is, that whereas the steel suddenly cooled in water may be broken by a sharp blow, in other words, has its range of resilience greatly diminished, in the latter case the metal has its rigidity greatly reduced, and its elastic resilience exalted, so far that from breaking up by a blow or a scratch, it is at once both toughened and strengthened, both as against steady strains and impacts. Nor are the conditions of the process, as here described, indispensable to the result, except in the case of very large masses, to which the process of tempering, known for ages, cannot be applied. The sword blade heated to a redness and quenched in cold water cannot be bent much more than a piece of glass of like size and form without fracture; but let the hardened steel be heated slowly over a fire until it is hot enough to cause tallow or oil to blaze off from its surface, and the blade be now quenched again in water, the result is the well-known strength and elasticity of the sword blade. The only point of real community between the two processes is that the change in physical constitution of the metal appears to take place at about the temperature at which fixed oils begin to volatilize and ignite. But the steel is a compound, and a most peculiar one. No simple metal, so far as experimental knowledge yet goes, presents the faintest trace of those phenomena which characterize more or less the chemical com-

pounds of iron and carbon wherever the percentage of the latter is so small that it is all in combination with the metal. Copper, for example, when heated to a full red or to any high temperature below that, and suddenly quenched in water, is not hardened nor yet tempered, but has its ductility and softness increased to the utmost and its elasticity reduced to the lowest point, and yet the copper may contain metalloids in some state of combination and in almost as large proportions as in the carbon in the finest steels. There therefore seems to be but a faint analogy, and that probably merely a superficial one, between the tempering of steel and this so-called tempering of glass. As to what takes place which produces the physical changes in either case we are almost in equal ignorance. The facts, however, as regards steel have been observed and recorded with considerable care ; not so those which respect this process of La Bastie, which was excited so much wonderment and some expectations as to useful results in the arts, which if the facts so far be correctly observed are likely to prove abortive. We can scarcely conceive any economic use to which glass which goes to pieces upon receiving a rough surface scratch—however otherwise resistant—can be put with any advantage. Glass sheets or plates for skylights, conservatories, lighthouse lanterns, &c., would be of little use against hail and storms if a fragment of grit lodged upon their surfaces would, when struck or rubbed, be liable to cause them to fall to powder. The burglar would find this toughened glass in the plate of a jeweler's window quite a boon ; and if, too, it should prove ultimately that this glass cannot be cut evenly and readily by the ordinary plate-glass diamond, that difficulty alone will, we apprehend, prove a bar to its application to glazing purposes upon any large scale. Nor would there even seem to be much advantage in the application that has been suggested to watch-glasses, which are always liable to be scratched, and in which a pocketful of glass dust would be no improvement upon three or four large fragments. Nor, indeed, whether the fact be that M. de La Bastie has obtained any patents or not, but yet relies on making a secret of the proper temperature of the glass and of the precise composition of his hydrocarbon bath, omitting the apocryphal temperature necessary in the air, does it seem to us that any considerable advantage can accrue to him as a discoverer beyond the fame of his having been the first observer of some facts of great physical interest. Any one financially interested would soon find out within what limits of temperature the process answered best. The range is very narrow, for if the facts be truly recorded, the temperature of the glass cannot be higher than that at which the glass softens so that the object would lose its form, nor lower than that at which glass begins to assume the rigid condition. For the glasses of wholly earthy bases, such as plate and crown, or white Bohemian glass, it will therefore be below a bright red, approaching a yellow heat in daylight, and for flint or other lead glasses below a dull red. The total reduction in temperature of the glass produced by immersion in the bath would appear to be a range of between 600 deg. and 800 deg. Fah. Again, as to the bath, it would be futile to suppose that there can be any chemical action between its material and that of the glass quenched in it. The effect, whatever its nature, must be a purely physical one, dependent mainly upon the boiling point and degree of viscidity of the liquid ; and we cannot but suppose also that these would be hit upon by a few trials. We cannot but think, therefore, that M. La Bastie would be likely to obtain a far better harvest in the way of honestly-attained fame were he fully and in the most exact manner to detail for the use of men of science every part of his very singular discovery. It is one which in its scientific aspects is likely to arrange itself as one of the most important guiding lights amidst the darkness of our ignorance as to the physical changes which takes place by change of temperature in matter. The loose speculations which have found their way freely into print, and pretend to offer a theory to account for the results of the process, are but darkening counsel by words without knowledge, while even the facts to be accounted for remain but imperfectly described ; let us have these and we can scarcely doubt that some of the

competent scientific men of Europe —such as Fizeau or Jamin, or M. Luynes, who appears to be already engaged in the investigation in France, or Stokes, Miller, and Clarke in our own country —will be induced to institute and carefully conduct such trains of experiment as may throw some additional light, and, so far as it may go, determinate in character, upon these phenomena, connecting them firmly with known physical laws. Such experiments must be conducted by refined methods and apparatus, and with a previous knowledge of physical optics that very few men, indeed, in any country possess. Had Brewster and Faraday been alive we should already, probably, have received from them much light. The former showed how the lines of strain, both of tension, and compression, in prisms of glass, produced by applied mechanical force, might be rendered visible by the aid of polarized light. Analogous methods and others equally refined, which we do not venture to suggest, will no doubt be employed by such physicists as we have named, and who may undertake this promising investigation. But certainly no light will be thrown upon it—theoretic or practical—by the experiments of the character of those said to have been made by Mr. Kircaldy. We have the highest respect for that gentleman as a faithful recorder of well-made and trust-worthy experiments upon the resistance of materials of construction to extraneous forces as ordinarily applied, but it is no disparagement either to him or to the apparatus with which he operates, to say that he is not the man for any such delicate and far-reaching research as is needed to throw any light upon this matter. The experiments stated, in the above lecture, to have been made by him upon the transverse resistance to static strain of this class are far from accordant, arising in part no doubt from the difficulties already referred to as besetting all such experiments upon a body so rigid as glass; but, probably much more from the specimens submitted to him not being all alike in resisting power, a circumstance which suggests that the process itself may be one deficient in uniformity of result. A lecturer who treats of a subject so full of difficulty as that of the La Bastie process might be expected to be equally certain and conversant with the facts he adduces, and it certainly is surprising to find it stated, as the basis for a somewhat obscure theory of the Rupert's drop, that glass, like water, possesses the property of expanding in volume whilst passing from the liquid to the solid condition. Water and bismuth are the only two bodies now known to increase in volume upon consolidation, and glass certainly does not expand when becoming solid from fusion, nor is it necessary to call in any such condition to account for the phenomena of the Rupert's drop, which was ably treated of by Dr. Brewster, although, as it appears to us, much remains before the remarkable phenomena presented by these drops can be said to be completely understood.

The most pertinent and valuable remarks that were made were those of Mr. Hartley, of Sunderland, during the discussion of this lecture. His view that the de La Bastie glass is no more than a Rupert's drop in another form is, probably, in the main true, yet it presents great difficulties, for how the unstable equilibrium of a Rupert's drop which has been shown to depend, as one of its conditions, upon the perfect form of equilibrium given to the drop by the mode of its production, can exist in a flat rectangular plate, still less in other and more irregular forms, it is difficult to understand.

Signaling on the German Railways.—Several railway companies in Germany are experimenting with different systems of signaling, their interest in the matter being quickened, not by complaints from the ladies, who have long enjoyed the privilege of *Damen-coupés*, but by the number of fires which took place last winter in sleeping carriages. Electric communication is found to be not only costly but untrustworthy, and the so-called "English" system of signaling with a line is not considered satisfactory. In short trains experiments are being made with a cord, which is carried by a ball and socket holder up to the steam-whistle.

— *Iron.*

ON MOLECULES.

From "Engineering."

The interest elicited by our remarks upon some of the phases assumed by water in one of its conditions, induces us to place before our readers some points suggested by the subject, and to state the views held by the most advanced investigators with regard to the ultimate form of water and matter generally, and its relation to the vaporous or gaseous state. The subject is one that demands our closest attention, for, upon a thorough elucidation and application of the beautiful hypothesis as to the structure of matter, which, of late, under the name of the molecular theory, has been so earnestly studied and so thoroughly elaborated, much of empiric practice in the application of motive power would be swept away with a benefit to science and humanity not to be lightly estimated. In the course of this article we shall, in the interest of junior students, carefully avoid all mathematical formula, and present the subject in its barest outlines, that he who runs may read.

It is possible to conceive of two states in which matter might exist, and from the times of the ancient Greek philosopher down to the present day, these two states have formed subjects for discussion—indeed, our most modern theory may be said to be merely a greatly improved form of one propounded ages ago by Democritus, and in its essential conception the very opposite of that set forth by Anaxagoras. The latter taught that all matter was incapable of infinite division, while the former held that, after a certain extent of divisibility had been reached, matter could be no longer subdivided, and the small particles arrived at called atoms—literally that which cannot be cut—would be the minutest possible in the universe. This is now the almost universally received theory, and by its aid certain phenomena can be explained, for which upon no other known hypothesis could any explanation be suggested.

The term atom has been exclusively appropriated by the chemist, while the mathematician and physicist has preferred to adopt, or share with him, the word molecule to signify those ultimate constituents of matter upon whose motions and relations depends the various states of all bodies, solid, liquid and gaseous; their temperature; and other properties.

The word particle is also freely made use of as involving no hypothesis, and meaning simply a small part of any body. Molecule has been defined by Maxwell as "the smallest possible portion of a particular substance;" and, again, as "that small portion of the substance which moves as one lump in the motion of agitation."

Every substance is now supposed to be composed of an immense number of molecules, which, even in the solid state, are never entirely at rest, and, in the gaseous, are in a state of perpetual violent commotion, rushing about in straight lines in all directions with inconceivable rapidity; and it is this perpetual bombardment, as it has been called, by these little particles that explains the known pressure of gas on the walls of any containing vessel, the incessant impact of the molecules producing the effect of one continual pressure just as upon the eye a succession of rapid flashes of light have the effect of one continuous flame. Of course the molecules, although they are supposed to be separated for a very considerable distance from one another, are perpetually meeting and rebounding, and thus their velocity is interfered with, but there is a certain residuum of speed left, resulting in a mean velocity for the whole. This mean velocity indicates also temperature, and, for the same substance at one pressure, the same mean velocity is always accompanied by the same temperature. But every different substance has a mean velocity of its own for a given temperature, and these have all been calculated, such is the extreme nicety with which the hypothesis is being worked out. Taking, for instance, one of the constituents of water—hydrogen—in the form of gas its mean velocity has been calculated by Joule at over a mile in one second—a speed far greater

than anything we have any practical knowledge of—far above that obtained in artillery practice. The exact velocity is 6,097 feet per second, at a temperature of 32 deg. Fah., and at the ordinary pressure of the atmosphere. A daring attack has been made upon the actual size of the molecules with a result that has every element of probability in its favor. Taking the theorem of Classius as a basis, Thompson has calculated that a cubic inch of gas contains 10^{23} molecules, *i. e.*, a hundred thousand million, million, million; and he deduced from certain optical phenomena in connexion with the thickness of soap bubbles, from the electrical conductivity of metals, and from other considerations, that the diameter of a molecule was about the $\frac{1}{500,000,000}$ of an inch.

To convey some idea of the amount of these magnitudes he says: "If we conceive a sphere of water as large as a pea magnified to the size of the earth, each molecule being magnified to the same extent, the magnified structure would be coarser-grained than a heap of small lead shot, but less coarse-grained than a heap of cricket balls."

It will be observed that we do not specify what gas this is, because a still further development of the theory shows every gas at a given temperature and pressure to contain the same number of molecules, having, however, different weights, and different mean velocities. But—and here comes the means of reducing the theory to a practical issue—the weights and the velocities so counterbalance one another that the resulting energy is the same for every perfect gas. For this argument the perfect equality in size of every molecule of one kind of substance is assumed; that they are so equal is, however, readily proved. Graham has shown how gases can be separated by diffusion through a porous septum; but, if the sizes of the molecules of our gas varied, it would be possible by successive filtrations to get different portions of the gas with molecules of different sizes. The density would then become unequal, and their combining powers different; but whether this separation is looked for in nature or by the hand of man, it cannot be found. Let hydrogen be taken from water, from a hydro-carbon, or from a fallen meteor, its properties, energy, and density, are always alike; and so with all gases. A very convincing proof of the molecular state of matter may be found by taking a cubic inch of water, and, by the application of heat, converting it, in a closed vessel of one cubic foot capacity, into steam. It will apparently fill it. Now if this steam were an expanded solid it would fill the space entirely to the exclusion of all other matter. Does it so behave? It does not. In the first place the result is little interfered with, whether the air is first exhausted or not; for the steam can be made to fill it though the air be there; an inch of ether may be added, and its vapor rises and fills the space as though nothing were there; an inch of alchohol could be similarly vaporized as though nothing were present. The same thing could be done with other volatile substances; and we could go on adding liquid after liquid, and evaporating all into the space at one time. This is very striking proof that the liquid in vaporizing, has had its particles widely separated, and so left room for other particles to be disseminated within its interestices. This position is still further strengthened by observation of the pressure; each liquid exerts a pressure in itself, and if a suitable apparatus be provided to receive the vaporized products and connected with a barometer, it will be found that the pressure of the mixed vapor is just the sum of that of the individual vapors.

Having now indicated the state of matter in the form of gas, that of liquids and vapors may occupy our attention. In a liquid the various motions of the molecules, vibratory, rotatory and rectilinear, exist in a modified form; the rectilinear is slight, while the other two are not much interfered with. If heat be applied the motion of translation is increased as in gases, and, at certain temperatures, different for most substances, vapor begins to form. Water gives off vapor at all temperatures; but this is not the case with all bodies, mercury, for instance, requiring a temperature above 10 deg. C. before it vaporizes. The dynamical theory of heat explains how this change of state occurs. The molecules being in rapid motion and

tossed about in all directions are prevented on all points but the surface of the liquid from escaping ; but here they meet with no resistance beyond that mutual attraction which exists among the molecules in the liquid state. But at the surface it will happen that some of them, by a combination of vibratory, rotatory and progressive motions, will be ejected with sufficient energy to carry them out of the sphere of the attractive force of the neighboring molecules, and they then assume the characteristics of gas, moving with the velocity described, and, in this form are truly particles of vapor. If the liquid be enclosed in some vessel, these vapor molecules in their motion of translation will at times strike the surface of the liquid and become imprisoned through the attractive force of the molecules, to be, however, replaced by other projected molecules. This process will continue, and the difference between the number of molecules sent out by the liquid and those caught back again becomes less and less till equilibrium is reached. The vapor is then said to be *saturated*, and its elasticity, under the circumstances, at its greatest point ; or, in other words, the vapor exerts its maximum tension at the given temperature and pressure. If then we attempt to decrease the volume by pressure, a portion will be liquefied according to the amount of pressure ; but the tension will remain the same. If, however, we pursue the opposite course and endeavor to increase the volume, we shall succeed, and the tension will be lessened; and the more we extend the volume the more exactly do we find it proportional to a reduction of pressure till at last it conforms to Boyle's law, which states that in perfect gases the volume is exactly inversely proportional to the pressure.

But this want of accordance of vapors at their highest state of tension with gases under ordinary conditions of pressure, &c., is more apparent than real, for it is found that the liquefiable gases, such as carbonic acid, nitrous oxyde, &c., when very greatly compressed, also fail to agree with Boyle's law, and act almost the same as vapors. It must not be forgotten that these changes of volume produce important calorific effects, as will readily be imagined when the molecular action is mentally followed. The pressure being now seen to be simply the sum of the energies of a multitude of impacts, it follows that if these impacts take place upon some body that gives way to the shock, the moving force of these molecules will be reduced by just so much as the body gives way to their violence; that is to say, heat or molecular motion will be converted into visible motion. And upon experimental inquiry, such is the case, the vapor or gas in expanding loses heat, and if the expansion be great, the cold produced may be most severe. On the other hand, when a gas is compressed, the molecules, instead of losing their velocity, have an additional quantity imparted to them, and the predicted and observed result is a manifestation of heat, *i. e.*, motion is converted into heat. In the production of steam the atmosphere has to be pushed on one side as it were, or the piston has to be forced away from it : here again heat disappears, and is rendered latent. So it is through the whole range of nature. Where heat or energy is lost sight of it is not destroyed ; it is simply stored up for future use, or converted into motion. Physical energy of every kind—chemical action, electrical action—is convertible into heat, and, as Thompson has pointed out, their tendency is continuously in that direction. "There is then in the present state of the known world a tendency towards the conversion of all physical energy into the form of heat."

Our brief survey of this subject, which possesses such a close and wonderful interest to every student of natural phenomena, may suitably close with a shadowing forth of the result which modern speculation and experiment inevitable lead to, and this we cannot do more explicitly than in the words of Rankine, which we extract from the *Philosophical Magazine* :

"Heat moreover tends to diffuse itself uniformly by conduction and radiation until all matter shall have acquired the same temperature."

"There is consequently, Professor Thompson concludes, so far as we understand the present condition of the universe, a tendency towards a state in which all physical energy will be in the state of heat, and that heat so diffused,

that all matter will be at the same temperature, so that there will be an end of all physicial phenomena.

"Vast as this speculation may seem it appears to be soundly based on experimental data, and to represent truly the state of the universe so far as we know it."

RIVERS AND MANUFACTORIES.

From "The Engineer."

One of the most difficult legislative problems in existence lies in framing good laws for the purification of a manufacturing country. It is apparently impossible to draw up enactments of this kind which will not bear hardly on large sections of the community. The welfare of the few should, as a matter of course, be abandoned for the good of the many; but the few will fail to accept the necessity with complaisance. For this reason, the utmost care should be taken to dissever the operation of the law from any appearance of harshness—by no means an easy task to perform. But there is a far wider and deeper question lying beneath the surface of the whole matter. It is quite within the range of possibility to legislate apparently for the good of the many, and with the best intentions possible, and yet to fail to attain the object sought. And it is to this phase of the question that we wish to direct particular attention.

Those who have devoted any thought to the progress of sanitary legislation in this country or abroad, can scarcely have failed to see that the movement in favor of the purification of rivers and the disposal of sewage is a comparatively new thing in the world. Twenty-five years ago people said very little about sewage, and the fact that a river was not clean called forth no comments. So long as sewage was got out of a town and into a stream, local authorities were quite contented, and Parliament took no trouble in the matter. As the country grew in wealth and luxury, and the desire for comfort augmented, better systems for cleaning our towns and our houses sprang into existence, and sons regarded with horror that in which their fathers saw nothing objectionable. This was partly due to the growth of refinement in the nation, and the feeling would no doubt have modified the course of legislation in any case. But a more powerful argument operated forcibly to render the interference of Parliament in sanitary matters essential. Great cities started up on the banks of streams, and as the streams received all the refuse of the cities, their pollution was augmented until it became intolerable to those who dwelt on their banks. Then the nation begun to assert that the rivers of the country must be kept pure ; and this is really the object had in view when sewage irrigation or precipitation is employed or demanded. The great sanitary struggle of the day is, in fact, to keep our rivers unpolluted. Now, it never was disputed until within a comparatively recent period, that rivers are the great cleansers of a country ; and to this moment it is almost impossible to see how any substitute for their operation in this capacity can be found. So long as the people of Great Britain confined their attention to agricultural and pastoral pursuits there was little difficulty in keeping the rivers clean. In the first place, great cities are impossible in a pastoral country, and whatever the population might be as a whole, the impurities to be disposed of proper to that population would be diffused over a large area, and no concentration of filth would exist. But Great Britain is not a pastoral, or agricultural, but a manufacturing country. Great cities have come into existence within her shores, and sewage is poured into her streams, in certain localities, in such volumes that oxydation and precipitation by natural causes are quite incompetent to keep our rivers pure. Then the law steps in, and compels us to refrain from throwing sewage into our rivers ; and so, instead of continuing to use the natural cleansers of the country, we are compelled to seek artificial means of disposing of sewage. We shall not enter here into any consid-

eration of the difficulties which attend this operation—they are familiar, no doubt, to the greater number of our readers ; nor shall we deal with non-manufacturing towns, the prosperity of which can be little affected in any way by the operation of sanitary enactments. In the case of manufacturing centres, however, matters assume a very different aspect, and in dealing with them the utmost caution is essential to avoid the passing of laws which may either prove a dead letter or cause serious injury to the property of our manufacturers.

If the worst comes to the worst, the inhabitants of a town can always get rid of what may be termed pure sewage. So far as dwelling houses are concerned, all that comes from them may be turned on to the land, and will assist to grow crops, and promote fertility. But not so with manufacturers. It is quite possible to pollute sewage, and, in certain cases, the refuse cast by manufacturers into sewers may be sufficiently great in quantity and deleterious in quality to render large volumes of sewage utterly unfit to put upon land ; and even if the evil does not attain quite to this point, it is certain that in many cases the quantity of sewage is impaired by the refuse mixed with it. The spent alkali, for example, from paper works, requires to be enormously diluted before it can be put upon land without destroying grass. It would, perhaps, be possible, under certain conditions, for a Local Board, to prohibit manufacturers from pouring certain products into the sewers of a town. For example, let it be supposed that the sewage of a town is rented from a Local Board, on the understanding that the sewerage is a valuable commodity. If, then, a manufacturer turns in, say, a quantity of sulphuric acid, he may practically render the sewerage poisonous to grass for the time, and so inflict serious injury on the tenant of the sewage farm. There is no reason, so far as justice is concerned, why the Local Board should not, in such a case, insist that the manufacturer must not pour sulphuric acid into the sewers. Up to the present the point has hardly been raised, because the rainfall and sewage have not been separated ; but let a comparatively small town, with a few large paper mills or dye works, once have the separate system of drainage, and send only concentrated sewage on to an irrigation farm, and complaints would quickly be heard. In such a case, what is the wretched manufacturer to do ? He cannot use the town drains, and he must not use the river. The reply will be that he must either hit on some means of neutralizing the noxious qualities of the effluent from his works, or he must abandon the business altogether. In the last alternative, thus stated, we have the objectionable side of sanitary legislation. In a word, it is possible to make laws which will ruin given branches of trade. Such laws are intended for the good of the many, but although they may promote health they may be inimical to wealth, and in that case, however good the intentions of the law-makers may be, the practical results of the operations of their enactments will be most unsatisfactory.

It is not difficult to cite instances in which it is impossible to keep streams pure and carry on certain branches of trade at the same time. For example, the water discharged from copper mines is usually excessively bad, and no means have yet been discovered of rendering it inoxious, which are at once moderate in cost and universally applicable. Something may be done under certain circumstances, by precipitating the copper on iron plate, as at the Amlwch mines, in North Wales, but even then the water discharged from the settling pits is destructive to fish. We need hardly say that it cannot be put upon land. There is no possible means of disposing of it but by sending it into the nearest river. The result of an enactment that the water from a given copper mine must not go into a river would be that the mine must be closed. Would it be prudent to enforce the law in such cases? Might it not be, altogether better for the nation, as a whole, that all the fish in a given stream should be killed, and that the copper mine should continue in operation? We shall not stop to answer the question. Those who advocate the purification of our streams at any price are very fond of asserting that if only manufacturers will but try they can easily purify their effluent, and pointing triumphantly to the operation of the Alkali Act, they say that what can be done to purify the air can be done to

purify the water. Now, we are not arguing that manufacturers should be left to follow their own sweet will and pollute streams as they please. Our object is not to deprecate sanitary legislation, but to urge caution in making and putting sanitary laws into force. The good sense of the country may be relied on to a great extent to protect trade interests, but it is not all-powerful, and nothing would tend more to retard progress in the right direction than first passing severe sanitary laws and then enforcing them without discrimination. In spite of all that has been said about the purification of the air, even those who are least particular will agree with us that the atmosphere of Widness is *not* delicious. To make the air of this town good and wholesome, it would, as matters stand, be essential to shut up the chemical works for which the place is famous. We need not say that to use the law for such a purpose would be unjustifiable and impolitic to the last degree. Again, what would become of the iron trade of the country if a vigorous law were put in operation to compel furnaces to consume their own smoke? Yet it would not be more difficult to make iron with smokeless furnaces than it is to avoid the pollution of rivers by feltmakers, dye works, chemical works, or paper mills. The fact appears to be that it is utterly impossible in a manufacturing region to enjoy all that purity of air and water which may be found in agricultural districts.

It is proper that Parliament should interpose to keep the pollution of our streams and our atmosphere within reasonable limits, but the existing degree of pollution of either would not justify the making of laws which might cripple the operations of the manufacturers to whom Great Britain is so largely indebted for her prosperity.

LIERNUR'S IMPROVED SYSTEM OF TOWN DRAINAGE.

From "Journal of Society of Arts."

PUBLIC opinion is daily growing stronger and stronger in favor of legislation to prevent or lessen the scourge of disease that arises from defective drainage, and to stop the pollution of our streams. It is particularly fitting, therefore, that through the medium of this Society attention should be drawn to a system of drainage which, it is averred, is the complete solution of the much vexed problem, sanitarily and technically, and it is anticipated financially also.

It is especially fortunate that the only part of the Liernur system, the practicability of which originally admitted of any doubt, has now been extensively in operation upon the Continent for between three and four years. The fact that it is successful in the highest degree will be apparent when I mention that everywhere it has been put into operation it has received the highest approbation, testified in a practical way by its extension, and that amongst the evidence that may be referred to are such reports as those of the Medical Commission appointed by the Kingdom of Saxony, the International Medical Congress of Vienna, and the whole of the twelve Medical Inspectors of Holland. These last, in a report to the Minister of the Interior, declare unanimously that "sanitarily and for the convenience of the inhabitants, the Liernur system is the best of all systems hitherto known." This favorable evidence has now been confirmed by numerous deputations and commissions from England.

My object, however, is not to string together such evidence, but to give to the Society a description of the principles and technical details of the system.

The end and object of sewerage works is, or should be, to remove the liquid refuse of a town in such a way that there cannot possibly be any pollution, by deleterious matters, of soil, air, or stream, and in such a way that no offence is given to sight or smell, and no habits

imposed upon the people which are likely to be neglected by even the lower orders of the population.

It will be readily admitted that the systems in use in this country cannot pass the standard thus laid down. The fault of all of them is that in one great common sewer there is an indescribable and unmanageable mixture of nastiness, which pollutes both soil and atmosphere, and which, with the exception of those few cases where effective irrigation-farming has been introduced, pollutes streams as well. Irrigation has been pointed to as the great panacea of the sewage evil, forgetful of the fact that it leaves untouched the two great evils of polluted air and soil, which, as much as anything, affect the health of the people.

The Liernur system, on the other hand, is founded on the old Napoleonic maxim, "Beat the enemy in detail"—"Divide and conquer." In other words, never allow any nuisance to get such accumulative power that it cannot be kept under perfect control.

Primarily, Captain Liernur lays down the principle that nothing of a seriously polluting character should ever be allowed to enter the common sewers. For this purpose it is evident that not only must night-soil, and the waste refuse of trade be kept out, but also the fatty and sedimentary products which find their way down kitchen sinks, and the *detritus* from our streets. If this be done, it is evident that the sewer water by itself, though not bright and sparkling, will contain in it no materials of disease to contaminate either soil or air, and will scarcely be dirtier than that which flows from every brooklet in the country after a rainfall.

To keep street *detritus* entirely out of sewers it is necessary that the gullies should be provided with apparatus to detain it. Such an apparatus, it will be seen by this drawing, consists simply in an iron bucket, into which the water, coming from the street, can enter only by a funnel, and from which it can only escape into the sewer by filtering upwards through a thick, loosely-woven straw mat, the mud in suspension being simply cast down into the box.

This mud can be easily removed by scavengers, the bucket in which it is contained being lifted and emptied into a cart. According to the pavement employed will be the frequency of this emptying process. In the ideal town of which I am speaking, Captain Liernur would select the improved wood pavement, as being noiseless, affording a good foothold for the horses, offering a free scope for evaporation and percolation, and as being easily scavenged by machinery. On such a pavement the *detritus* would be necessarily small.

To those who would advocate letting the mud into the sewers I would say, remember that it must be dealt with somewhere, either by separating it from the sewage at the outfall, or dredging it out of the river. Is it not better, therefore, to deal with it at the start, and prevent not only its depositing, choking and fouling in the sewers, but its complicating the sewage problem thereafter. At Belfast, for instance, they have periodically to break open the sewers to clean out the mud.

Next, it is requisite to keep out of the sewers all the waste products of industry. For this purpose it is absolutely necessary that legislation should compel all manufacturers to clear their water before passing it into the sewers. The reason for this, on the principle "divide and conquer," is obvious. It is easier to deal with substances of which we know, or can easily ascertain the component parts, and the different variations that may occur, than when mixed with sewage and waste of all other kinds. In the latter case it becomes an indescribable mixture no man can master, and for which if one day a golden receipt were found, the next day's variation would render it useless. The question as to who should bear the cost of separate purification is one between the manufacturer and the authorities, in no way affecting the principle laid down. As a rule, and as has now been found out by practice (see the working of the Alkali Act and the purification of dye and bleach works, as exemplified by Mr. Thom at the Society's Rivers' Pollution Conference), I believe it would pay the manufacturer, and unless legislation compels him to do the work, there is no possible solution of the sewage problem.

The question for the engineer is, how to test the obedience to the law. Captain Liernur's plan is simple. On the drain-

age pipe from the factory a bend is made, in which some of the water flowing off must always be present. From that bend to the surface of the side walk is an upright pipe, covered by a lid. Through this pipe, by means of a small hand-pump six inches long, the inspector of nuisances can at any time take a sample for analysis.

The sewage problem is not always complicated by the question of manufacturing refuse, but all towns have in some way or another to get rid of human excrement, which is the most dangerous, and at the same time the most valuable, part of sewage. That it is absolutely necessary for sanitary perfection that it be kept out of the common sewers I think no one will deny, if its separate collection can sanitarily and conveniently be effected. To be perfect, such collection involves a great many conditions, which have been well expressed by the Senior Medical Inspector of Holland. A review of them is necessary in order to understand what the pneumatic subdivision of the Liernur system really accomplishes :

"In the first place, a form of closet had to be constructed for use in combination with this system, really perfect in a sanitary and æsthetic sense, inoffensive to sight and smell, and simple and cheap enough for all classes of society, including the poorest and most thoughtless, and yet permitting to the rich those luxuries to which they may be accustomed—qualities which the water closet, as is well known, does not possess.

"Secondly, the use of the water closet for those who could afford the expense of it and desired it, had to remain possible. This demand has been, among many others, a stumbling-block to the introduction of every pail-closet or tub-closet system ever known.

"Further, no laborers had to enter the houses, nor wagons and horses to be seen in the street to remind people of the work of removal, and thus be a nuisance. The work had to be accomplished without necessarily coming to the knowledge of any one, or attracting undue attention.

"But there is another point. As hygiene prescribes a daily removal of fæcal matters at the least, the work had to remain possible from a financial point of view ; that is, a great many closets had to be emptied by but one single operation. This involved a very difficult problem ; one closet of a row of houses containing much, another a little, and many, perhaps, nothing at all ; there were resistances to be overcome, having the greatest differences, by the application of but one motive power at one given moment, and this without failure or faltering. And, notwithstanding this difficulty, the work had to be done without requiring a complicated mechanical apparatus. Finally, no gases could be allowed to escape during or after the process. The pollution of the soil had to be absolutely prevented, and all danger whatever from infection avoided, without, however, destroying the agricultural value of the manure."

To the conditions above stated I would add another most important one. It is, that when from accident, neglect, or as in the case of solitary houses from convenience, the emptying process does not take place daily, the material must be so confined that in no way can anything escape to contaminate air or soil. And further, I would add, that the fatty and sedimentary products of kitchen sinks, which are the same in substance as fæcal matter, with this difference that they are not by several days so far on the road to decomposition, should also be removed under similar conditions to fæcal matter. In Holland, where these matters find their way fresh into the canals at once, and form good food for the fish, they will not trouble to adopt the Liernur system of collecting them, but in this country it is desirable to exclude them from the sewers for two reasons. First, that in time they would give off organic matter in solution and be polluting; and secondly, that their valuable manurial qualities would be lost to the town.

Captain Liernur's pneumatic subdivision for the collection of excrement and sink refuse is the most novel part of his plan of town drainage, for although the other subdivisions have many novel features and improvements, it was the only part about which, previous to its being tried, there could be any doubt as to its being technically possible. These doubts have now been removed by four

years of successful operation. As remarked by the Senior Medical Inspector of Holland, "it is due to the inventor to state that the works executed by him in Amsterdam and Leyden show that he has overcome all the difficulties completely;" and the Director of Public Works supports this by stating that "never has there been in the history of applied science an invention which has come to such perfection in so short a time as the Liernur system."

I will now draw your attention for a while to the technical details of the pneumatic system.

Any large town would be divided into districts of from 250 to 1,000 acres according to local circumstances. Each district would be separate and as independent from any other as if it were an isolated town. Each such district is again divided into small drainage complexes or areas varying from 10 to 50 acres, also according to local circumstances. Each of these little drainage areas is provided with one air-tight cast-iron tank, built in sections so as to be easily enlarged, and with spherical ends to resist atmospheric pressure. This tank, which for distinction sake I call a street tank, is placed at a convenient spot, generally where two or more streets meet, and about three feet under the pavement. From the tank along the several streets extend air-tight cast-iron main pipes five inches in diameter, each perfectly separate and independent of each other. These pipes are connected by branches with the closets of the houses, and are preferably placed in the rear, so as to prevent as much as possible the tearing up of pavements, and to get at closets by the shortest route.

It will be understood that if a vacuum is made in the street tank, a motive power is stored up, which can be let loose upon any given street pipe, and will literally suck towards the tank the contents of the closet pipes. A new vacuum can then be created, and the emptying into the tank be completed.

The question then occurs, how is the vacuum made, and how are the contents of the tank removed. To this I must answer that while the system is being put into operation, that is before the central pumping station and its connections are complete, both the vacuum and emptying processes are the operation of a movable air-pump engine and an air-tight tender, which once a day visit the street tank for the purpose. This mode is merely temporary, and enables the system to be begun in any number of places at the same time without inconvenience. It is largely used in Bohemia, where the system is extensively in operation in barracks and large factories, the demand for the manure in its undiluted fluid côndition for the cultivation of beet being very great, the price given being equivalent to 8s. per head per annum. Even this temporary method is without any annoyance to sight or smell. Professor Volger says, speaking of the works at Prague :

"I have repeatedly witnessed the operation with real pleasure. Once an elegantly dressed lady with her servant came close to me, and I noticed how she stooped down over the mouths of the reservoir, watching carefully, with warm hearted interest, the various manœuvres, without the slightest idea of the loathsome substance which was being handled."

The traveling air-pump, engine and tender, however good as a temporary measure, are undesirable as a permanence, nor do they form part of the system when complete. A central station is chosen in which are erected two or three air-pump engines, the aggregate horse-power being only what is required for working purposes, and the division into two or three engines being for convenience in case of cleaning, repairs, or accident. Under the building are air-tight cast-iron reservoirs, in which the engines maintain a vacuum of about three - fourths atmospheric pressure. From the reservoirs are laid, by the most direct routes, air-tight pipes, called central pipes, also five inches in diameter, passing by, and by a couple of connections communicating with, each street tank. One connection is with the top of the tank, and by it air only can be sucked out. The other connection goes down into the well of the tank so as to suck up its contents and remove them to the central reservoirs.

The operation, then, is the following : The air-pump in the central building maintains during the day a vacuum in

the reservoirs underneath, and in the whole length of the central pipes connected therewith. Patrols of two men each parade the district like turnkeys. Coming to a street tank they open the lids, by which access it given to the cocks which shut off each pipe from the tank. One man fixes his key upon the cock connecting the central or vacuum pipe with the tank, and the other has his upon the cock belonging to one of the street main pipes leading to the houses. The moment the first man turns his key he opens the connection between the central station and the tank, the air contained in which is at once exhausted, and a vacuum established, the extent of which is indicated by a small vacuum meter. He then shuts the cock, while the other man, by turning his key, lets loose the force upon one of the pipes leading by its branches to the houses. This action repeated once or twice brings the fæcal matter into the tank. In Amsterdam, for instance, there are as many as 138 houses whose closet pipes are thus cleaned out at once. In the same way a second, third and fourth pipe, each leading to different streets, may be dealt with, and the whole fæcal products of the little drainage complex belonging to the tank be thus collected in it. Before leaving the tank the matter must be despatched to the central station, and this is done by simply opening the second connection of the vacuum pipe, which dips into the well of the tank, when all the matter is at once sucked up and dispatched towards the central station.

So the men patrol the district from tank to tank, simply turning a few cocks; and such is the wonderful simplicity and ingenuity displayed by the inventor, that, with the exception of these cocks, which are of the simplest possible construction, and can be taken up and examined at a moment's notice, there is nothing movable, or which could get out of order, in the whole system of pipes, from and including the closet to the reservoirs of the central building.

The theoretical difficulties to be overcome were great—some closets would be much farther off from the tanks than others, and some might have received no material during the day, and other unequal quantities. It might be imagined, therefore, that by reason of these variations the vacuum might be destroyed and the emptying process prevented. To explain why this is not the case, I must first tell you what cannot be done. It is impossible to propel liquid any great distance through a horizontal pipe by air pressure. The piston of air would break through the column of water, cast it down on the lower segment of the pipe, and passing over would destroy the vacuum. It is evident, therefore, that Captain Liernur could not use horizontal pipes. What, however, can easily be done, is to raise fluids vertically, as in a pump, and bring them to the top of an inclined plane, down which they will flow by their own gravity; consequently, all Captain Liernur's pneumatic pipes are a succession of wave lines, being composed of inclines varying from 1 in 5 to 1 in 250 before the street tanks are reached, according as the fluidity of the matter increases. I may here say, that before reaching the street tanks, and even where water closets are not used, the matter is reduced, by the powerful action of the atmospheric shock, to a consistency resembling that of the thinnest of chocolate. Now, Captain Liernur gives to every branch pipe from the houses to any one street main the same aggregate of vertical risers, breaking them up to hop over an intervening gas or water pipe, or according to convenience. Now, a pump can never empty all the water contained in the receptacle pumped from. There is a minimum that it can never remove. In the same way in these risers, which act like pumps, there must always remain a minimum quantity of fluid just sufficient to fill the riser. In a state of rest this minimum is partly in the riser and partly in the lower end of the gradient of the pipe, forming a complete lock-off of one gradient from another, and a perfect resistance to the vacuum being destroyed even though any particular pipe may have received no additions since last the emptying process took place. The best example I could give of this would be to take two branches from one main pipe, and opposite one another as in the rough sketch. Suppose the riser to be in each case one foot and the branch 100 feet long, with a gradient of 1 in 100; the branch on the right leads, we will say,

to the house of a small family, producing one foot of fluid matter, or just enough to fill the riser, and that on the right to a barrack, where more than a hundred times as much may be expected. We have, therefore, in the barrack pipe a mass filling both pipe and riser, and ready, on the the slightest force, to discharge into the main or street pipe. On the other hand, in the branch pipe of the small family, there is the minimum quantity collected at the foot of the riser. The sucking action is now put in operation in the main pipe. What is the result? The pressure of the atmosphere begins to act, and the barrack pipe rapidly discharges into the main pipe, while the smaller quantity is simply climbing up the riser, and before it has got to the top of the riser to be in a position to discharge, all the surplus quantity in the barrack pipe has gone, and that which is left is simply equal to that minimum which, as I said before, cannot be withdrawn. In this way the fullest pipe always begins to discharge first, the next more full waiting for it, and so on, until the minimum is reached, when simply air breaks through. It is thus that Captain Liernur turns natural laws to his own purposes, and contrives that the minimum quantity gives the maximum resistance, and the maximum quantity the minimum resistance.

As I mentioned before, one of the great advantages of the pneumatic system is that it does not forbid the use of the water closet to those unwilling to give up the use of that expensive and oftentimes troublesome luxury. As, however, all the water added has hereafter to be got rid of, Captain Liernur stipulates that, if economy is to be studied, it is absolutely necessary to have a form of closet, of which there are several known, which only allows of a limited quantity of water being used. His own improved water closet, of which a quart of water is and must be used at each sitting, independent of the will of the individual, has been greatly admired, as being simple in construction, and not likely to get out of order, or to allow of freezing in winter. It would take up too much of your time to describe this, especially as I wish to draw your attention to the Liernur closet without water. This is intended for the working classes, who cannot afford the more expensive luxury, and who would abuse it if they had it. These form 75 to 80 per cent. of our population, and the Liernur closet suitable for them has been declared to be as inoffensive as the ordinary English water closet, and, but for the prejudice existing in favor of that convenience, as well fitted for the rich as for the poor.

The pneumatic privy has no movable mechanism at all, and is used without any water for flushing. The excreta falls into the bottom of a deep funnel, but the size and position of the seat opening is so arranged, and the shape of the funnel is so made, that the extreme area in which the excreta can fall is practically as much limited as would be the case in an ordinary chamber-pot. The effect is that the excreta falls and is collected in a pocket below of but small compass, without touching the sides of the funnel, offering to the air a surface of only five inches. The pocket referred to is one arm of a short bent tube or syphon trap, discharging in a soil-pipe. This discharge is effected by the weight of the excreta, fluids and solids, themselves, each new deposit forcing the former out. Thus the older matter is automatically shut off from further communication with the outer air, and it being well known that no fermentation capable of generating elements dangerous to health takes place within the first thirty hours after production, it is evident that the small surface of fresh substances exposed to the air could at the utmost only throw off offensive gases. To carry these off, however, each funnel is in the upper part made double, the space between being provided with a two-inch ventilating pipe placed close under the seat and leading to the outside of the roof of the house, and furnished on top with a so-called Wolpert's air-sucker. This little contrivance, scarcely known in this country, is very simple, having no movable parts whatever, but is singularly effective; the slightest and almost imperceptible motion of air (which in towns is never quite still) causes an upward current in the pipe. The result is that when the lid is removed from the seat opening a current of air strikes at once downwards into the funnel. From this it is evident that under no circum-

stances can an offensive smell escape from the funnel into the apartment. The funnel itself being of a dark color, it throws no reflected light on the excreta below. It is plain, therefore, that there can be nothing to offend either the sense of sight or the sense of smell, and this is all that can be expected from the best water closet.

Attention must be called to the fact that the pocket of the soil pipe into which the overflow of the privy funnel proper takes place is also ventilated. This pocket, being a bent tube discharging into the branch-pipe, is the real receptacle from which the fæcal matter is permanently removed; all the same, whether it belongs to the water-closet or the pneumatic privy of the system. The pipe provided for the ventilation alluded to serves at the same time for admitting the atmospheric air for the pneumatic process. Hence such air does not enter through the seat opening, nor is the matter in the closet itself removed by pneumatic force.

I have now to describe how it is that the sedimentary products of the kitchen sinks are separated from the rest of the house water, and carried off by the pneumatic pipes. That they are thus separated is due to an exceedingly ingenious apparatus Captain Liernur employs for separating them from the household water running off to the common sewer. It is a trap placed at some suitable spot in the open air, into which all the kitchen and household water on its way to the sewer discharges. In order to flow off into the sewer, all this water must pass upward through a close grating, which acts as a strainer. The sediment is thus thrown down into a sort of pocket, which stands in communication with the privy soil-pipe. When now the pneumatic blast takes place, the pocket of the sink is cleaned simultaneously with the closet pipes, the air to do this, which enters through grating, blowing it clean at the same time.

Before coming to the treatment of the matter collected, at the central station, I wish to say a few words as to the remedies for accidents and stoppages. Remember that the motto of the system is "divide and conquer," and see how this is carried out in every detail. To prevent foreign substances being thrown down and stopping up the pipes, the throat of the privy funnel you will see is made narrower than the pipes are, so that theoretically everything passing the throat will go further, and the most extraordinary things do go through in practice. As a further precaution the closet syphon is crossed by an iron bar, dividing it into two equal spaces. Anything that is small enough to go through will never create any stoppage. Larger articles simply stop up the closet itself, and give the person who transgressed the trouble of removing them, a lesson found in Holland amongst the poorest people to be quite effectual. Further each branch pipe from a house is provided with a stop cock accessible to the officials, by which any house can at any time be shut off from the rest of the system. Presuming a stoppage possible, the whole pneumatic power could be concentrated on any particular house pipe. Such things as leakages again do not occur, and if they did they would be closed up by the earth or substances drawn in by the suction power. In fact it would be impossible to keep a leak open even if desired. But what would be done in case of breakage, is an inquiry I have heard, and the answer is that one would do the same as if a water pipe burst—Mend it! There is this difference, however, between the two cases, a water pipe is so much more likely to break as the pressure is outwards. In the pneumatic pipes the pressure is inwards, quite a different thing. Supposing, however, a pipe did unaccountably break, a thing that has not occurred in experience in the shifty and uncertain soil of Holland, how far would it affect the system? If in the house, the repair could be made at once with or without shutting off the house. If in the branches or main pipe, it could at the utmost affect the houses upon that pipe. Now on account of the risers, the pneumatic pipes never need be deeply laid; below frost depth, that is about three feet, is quite sufficient, so there is no difficulty there. A more serious affair would be the breaking of one of the central pipes communicating the vacuum to the street tanks. This could not fail to be discovered, localized and repaired at once. Suppose, however, an extreme case, in which the repair could not be effected

for a whole week. Then there are two ways open. You can go back for the time to the movable air-pump, or you can simply not perform the emptying process for a week instead of daily as required by the system. This delay has often taken place at Amsterdam through the intentional negligence of an opponent of the system who was in authority. Remember it is the pipes only, not the closets which are emptied by pneumatic force, and there is room in the pipes for a week's product. Indeed, in applying the system to isolated houses on the outskirts of a town or in the country, without any tanks or street pipes, the closet pipes are only intended to be emptied once a week.

In case any one should think that fermentation would set in in the closed pipes during that period, I may mention that the Dutch authorities tried the experiment for thirteen months, and found no change.

I have especially dwelt upon the chance of accidents and their effect upon the system, as I have found the subject quite a bugbear in the eyes of many.

I have now to describe what is to be done with the matter collected at the central reservoir, namely, its conversion into *poudrette*. This part of the Liernur system has not yet been tested on a large scale, although the practicability of it has been sufficiently proved both by actual trial and by experience in sugar-refining, in which a similar process is carried on.

It is a well ascertained fact, that of the heat contained in the steam of a high pressure engine, employed in working the air-pump engine for collecting the matter, but 7 to 8 per cent. are converted into power, the remaining 92 per cent. escaping with the exhaust steam. It is this steam, superheated by being passed through a Green's economizer, and made dry again, that Captain Liernur uses for the drying process. It is conducted through pipes in an upright hermetically closed boiler, into which the fluid manure, after being mixed with a little sulphuric acid, is conducted, and in which by the heat thus imparted a rapid boiling takes place. This is assisted by the fact that a partial vacuum exists in the boiler on account of the vapors of the evaporation being condensed in another receptacle. This other receptacle is engaged in the second or drying process, and consists of a hollow drum of thin red copper, fifteen feet long, and two feet in diameter. This drum revolves in a trough of the already thickened matter, and is itself placed in a hermetically closed vessel, in which a vacuum is maintained. What with the heat imparted to the drum from the inside by the vapors from the first boiling which pass through it, and the vacuum outside, the thin layer of fæcal matter it takes up is thoroughly dried in the course of one revolution, and is scraped off by a fixed knife, falling in little shavings into a box below.

Now, whatever manurial ingredients there are in the sewage must be in the *poudrette*, the air, or the vapors. They cannot be in the vapors, for these come out as pure distilled water, nor in the air, for a vacuum is maintained in the vessel; therefore they must all be in the *poudrette.*

As the *poudrette* has not yet taken its place as an article of commerce, I will not enter into any estimates as to the revenue to be derived from its sale. I would merely point out that it is the pure undiluted material, in a strong concentrated state, and capable of being stored for any length of time, and that I firmly believe that in a town moderately densely populated the revenue would be sufficient not only to cover the annual expenses but to pay the interest of, and redemption on, the cost of the works. In other words, that the pneumatic system would practically cost the ratepayers nothing.

For a similar reason I will make no estimates of cost, as this, as in all drainage works, varies immensely, according to local circumstances.

The sanitary view of the pneumatic system is best described in the following sentences from the account by the Senior Medical Inspector of Holland :

"SANITARY.—The excreta are, from the moment the closets are emptied to the moment when the process is finished and they are converted into dry powder, absolutely deprived of all chance of doing harm, being locked up from first to last in air-tight vessels. The powder itself is harmless, because fermentation in

a dry state is impossible. The water of the excreta has also become harmless, because being driven out by evaporation and condensed again (the vapor passes through an ordinary condenser), it returns to the public streams as distilled, and consequently, pure water. And the gaseous products of the evaporation, perhaps still containing germs of disease, are blown by the air-pump engine, with the rest of the air sucked up out of the tubes and pipes, into the fire place of the boiler, and there are completely burned. No matter, therefore, how infectious the excreta may have been, their power to work evil is stopped forever."

In support of this, I may add that official statements at Leyden aver that the district where the system is applied was formerly noted for the prevalence of typhoid and diphtheria, and that these diseases have now disappeared entirely. Similar evidence is given by the Amsterdam authorities.

Having described the pneumatic subdivision of the Liernur system, I must now shortly state how Captain Liernur would provide for the ordinary drainage, as distinct from the sewerage, if the town were perfectly virgin in this respect. This part of the system is of less interest in England, because most of our towns are sewered, or at any rate have the rudiments of sewers, which they would be unlikely to displace for his improved sewers. In their case he would simply apply the pneumatic system, and, if they liked, his mode of removing street *detritus*, thus relieving the sewers of all dangerous matter. But in a town entirely new as to drainage, he would never adopt the present system, by which not only is great cost incurred, but pollution of soil rendered unavoidable. He would construct the ordinary sewers of vitrified earthenware, so as to be practically impervious, and then nothing would get either in or out except through the proper channels. To provide for the drainage of the subsoil, for which at present the common sewer serves by its porosity, he would follow the farmer's plan of laying agricultural drain-pipes, these emptying at intervals into the ordinary sewer below. These subsoil drains would be laid so as to keep the subsoil water permanently at its lowest level, thus preventing the fluctuations, which cause the alternate inhaling and exhaling by the earth of the atmosphere. The sanitary results of such fluctuations are thus described by Dr. Alfred Carpenter:

"In a porous soil, which easily allows of the rise and fall of the water-line, an amount of air finds entrance and exit equal in volume to the quantity of water which occupies the interstices of the earth. If the soil is impure from cesspool soakage and other sewage abominations, the air drawn into those interstices, as the water-line falls, becomes naturally loaded with the results of sewage decomposition. As the water-line rises this air is expelled and adulterates the purer atmosphere above. If the area is an inhabited one, much of this finds its way into the basements of the houses built upon such a foundation (it gets out more easily there), and the inhabitants naturally suffer from the effects of foul air. If the subsoil is drained by sewer pipes, and the latter are not ventilated in the most efficient manner, another evil also arises. The sewers which were pervious, and allowed leakage into the subsoil of both air and water, which passed downwards, are now sealed to some extent, and all sewer gases find their way into the houses direct. But this is not all. The rise of the water-line is attended by certain evils. Typhoid, and its allied diseases, become prevalent, but as the water-line falls again, another set of diseases become prevalent also, the intermittent class—ague, neuralgia, rheumatic disorders, are rife. It is found in ague districts that the drying, which naturally follows upon the fall of the water-line, is accompanied by epidemics of intermittent fever and its allies, with all those acute sufferings which are called tic, brow ague, megrims, *et id genus omne*. So it becomes the interest of the inhabitants of such a district to keep the water line as nearly as possible at the same level, for its rise or fall is always followed by damage to public health."

Besides the sanitary advantages, there are technical advantages which effect such a saving in cost that these subsoil drains, and the sewers, proper, can be

constructed for about as much as the present imperfect system. The sewers are made much smaller without fear of bursting, even when full, because of the permanent pressure outside of the higher subsoil water. The current in them will at all times be more swift, and hence more cleansing in its action, and if the water contained in them, deprived by Captain Liernur's plans of putrescrible matter and manufacturing waste, be allowed, without further treatment, to enter streams, his sewers can take the most direct route to the nearest water course, thus saving the enormous expense of huge main and intercepting sewers now so much used to carry the whole of the sewage out of town.

The above description of the Liernur system is necessarily brief and imperfect. Any one wishing for minuter details, I would refer to a long technical account written by me in the *Sanitary Record* of 21st November, 1874.

In conclusion, let me say that to strangers to the system a number of theoretical objections will be sure to arise, the answer to which is that in practice they do not arise. The subject, however, is of such paramount importance for England, that a Government official inquiry into the system is very desirable. In this I am sure every one will agree with me, if, as I hope, in the preceding remarks a *prima facie* case has been made out.

HEAT ABSORBED BY EXPANSION.

By S. W. ROBINSON, Professor of Mechanical Engineering, and Teacher in Physics in the Illinois Industrial University.

Written for VAN NOSTRAND'S MAGAZINE.

An article in the March number of the Magazine, by Professor H. S. Carhart, of the Northwestern University, indicates, as well as intelligence which has come to the ears of the writer regarding the Professor's experiments, that he is doing good work in the line of College Physical Experiments. Those interested in Western institutions of learning are glad to realize the fact that experimentation as a means of demonstration in educational classes is so widespread as to have reached some of our Western universities.

Though Professor Carhart deserves much credit for his fine experiments of a high order, yet we fear that he has allowed himself to get a little off of the right track in his reasoning, as set forth in the article above referred to, reasoning which the writer has waited several months to see set aright, and which, it is thought, ought not to go uncorrected.

I have, however, only one point to call particular attention to, and that is in regard to the performance of external work by the expanding gas while the receiver is being exhausted by the air pump. The Professor supposes, doubtless by oversight, that in such an experiment the operator performs the external work of expansion of the gas in the receiver, by his own effort in lifting the piston from the gas, a position probably more readily taken, on account of another seeming explanation of the disappearance of heat.

When the piston is raised by the operator, what constitutes the effort? The pressure of the air upon the top of the piston must be lifted. What does it? The pressure of the gas beneath the piston, together with the lift exerted by the pumpman. In exhausting a receiver, the first stroke will be accomplished with less effort than a stroke near the completion of the exhaustion, if a plain single acting cylinder is used. Why? Because the gas in the first stroke, having a greater pressure, performs more of the work of raising the piston against the constant pressure of the outside atmosphere. In other words, the gas in the receiver does perform external work, and, so long as any gas remains in the receiver, continues to aid the operator. If the gas in the receiver were prevented, by a stop-cock or other-

wise, from entering the cylinder while the piston is raised, the operator would perform the whole work of lifting the atmosphere, and the effort, it is readily seen, would be greater with the form of pump supposed, than if the gas were allowed to enter the cylinder freely. When the gas is excluded from the cylinder as the piston is raised, and retained in a fixed elevated position, producing a complete vacuum beneath, what occurs by opening the stop-cock? The reply is: "why, the gas, of course, now performs no external work." Still the receiver will be found cooled as before. Examine the cylinder of the pump. It is heated. And this heating will exactly neutralize the cooling. The gas in the receiver performs work, external to that remaining in it, by ejecting a portion into the cylinder, this work being stored in the moving particles of gas. As they collide against the interior of the cylinder, heat is generated, and just enough, when the particles have come to rest, to represent by that heat the work of expansion having taken place in the receiver. This is in fact nothing, but the famous experiment of Gay Lussac, and Dr. Joule. See Tyndall, *Heat as a Mode of Motion*, p. 89. Maxwell's *Text Book on Heat*, &c. In the exhaustion of a receiver by an air pump, if there were no external pressure, as of air, to be overcome, the piston would need to be held back to prevent its rising too rapidly. In other words, the piston would under these circumstances raise some certain weight. This is the very external work which the gas must perform, and which of course must cool it, as indicated by the pile.

Again the refrigeration of the receiver can hardly be due, to any great extent, to the motion produced among the particles of gas, because this motion, in the receiver itself, must be insignificant. If not for the first *quarter stroke*, that of the succeeding quarter strokes must be, because here the cooling after the first could be due only to the *difference of the motion* in succeeding quarter strokes. Also the motion of the gas in the receiver, caused by so slight a disturbance as produced simply by the departure of a portion of the gas, must involve an amount of work extremely insignificant when compared with the raising of the weight as above mentioned. We must therefore conclude that the refrigeration is due for *very nearly* its entire amount, and when the gas in the receiver has come to rest after the pump strokes, to its *entire* amount, to *external* work.

BALANCED VALVES IN LOCOMOTIVES.

From "The Engineer."

Many and varying estimates have been made concerning the power wasted in overcoming the friction of slide valves, and probably on no subject has there been a greater diversity of opinion. It has been assumed on the one hand that as much as one-fourth of the power of an engine is thus wasted, and those who hold this doctrine point triumphantly to broken and bent valve spindles as so many proofs that they are right, and that their judgment is sound; others maintain that the loss of power is nominal, and they adduce as evidence that they are right, link motions and eccentrics which have run for years almost without wear. The truth is, that neither party accurately expresses the facts. It is not to be disputed that slide valves do work with a good deal of friction, and so waste power when unbalanced; but it is quite certain that they can never waste one-fourth of the whole force of an engine. Scores of balanced valves are in the market now, or have been, and many of the systems of balancing, or taking off the pressure from the backs of the valves, have been adopted with success in marine and stationary engines, but none appear to have given satisfactory results with locomotives.

In this country there is, unfortunately, not so complete and thorough an interchange of ideas among locomotive super-

intendents as is desirable, and matters are not much better in the United States. There, however, exists the Master Mechanics' Association, and that society appears to be doing really good work, by appointing committees to investigate certain questions and obtain answers from various railroads concerning the experience of the locomotive superintendents. One of the most recent subjects discussed has been the efficiency of various systems of balanced slide valves as applied to locomotive engines. The results of the inquiry are instructive. Fourteen locomotive superintendents have replied to the questions of the Valve Gear Committee. These replies go, on the whole, to show that no satisfactory valve has yet been produced, and that nothing is better than the ordinary slide valve. Some of the valves are well known, others but little known in this country. The evidence concerning them is easily summarized; thus Mr. Hayes, of the Flint and Pere Marquette Railway, tried Richardson's valve, which he ran for two months or about 5,000 miles. The valve seats were in good condition, but the valve leaked badly and was removed. The ordinary valves spared the seats just as much in running the same distance. Mr. Taylor, of the Old Colony Railway, tried no fewer than five varieties of balanced valves, and pronounces them all worthless. Mr. Thompson, of the Eastern Railroad, has used Adams' valves—well known in this country—with good results. The ordinary slide valves in his engines required repairing after 45,000 miles; the Adams' valve ran 66,000 miles. On the Terre Haute and Indianapolis line, balanced valves have been tried with a moderate amount of success. In the course of the discussion which followed the presentation of the report, it became apparent that the general current of opinion was against balanced valves, because they gave no advantage with the increased cost and complication.

It is certain that when large valves are used, as in marine engines, some arrangement must of necessity be adopted to take the pressure off the back, and it can hardly be disputed that if a satisfactory device could be employed with locomotives a decided advantage would be gained; but the device has yet to be obtained, and a wide field for invention still remains unexplored. As regards saving of power, the question may resolve itself into a matter of economy of fuel. Now, all the evidence obtained in America goes to show that no saving of fuel whatever is realized by even the best balanced valves tried. But the question may be regarded from a totally different point of view. A balanced valve renders the handling of an engine easy, and saves wear and tear, not only in the valve and cylinder faces, but throughout the entire valve motion. Some of the American locomotive superintendents stated that with balanced valves the reduction of friction was so great that the reversing lever would remain in any position in which it was placed, although the detent was not in a notch in the sector. But there was also testimony to show that the valves which worked thus easily were all liable to blow through, and that some of them blew so badly that their use actually increased the consumption of steam. It does not appear that any of the speakers were acquainted with Beattie's valve, as used on our South Western Railway with great success; but this can hardly be called a balanced valve, closely resembling, as it does in practice, the old "long D" used by Watt. One proposal came out during the discussion which is well worth attention. It is that valves and seats should have chilled faces. It does not appear to us that any difficulty would be met with in carrying out this system of construction. It is eminently simple, and the excessive hardness of a chilled surface is well known. The experience of one of the speakers is worth notice. Mr. Jackman, of the Chicago, Alton, and St. Louis line, tried a device which we shall allow him to describe in his own words:

"We are using now, on three or four engines, another thing, and I want to state what it is so that every one can take advantage of it. We plane out a groove on the bearing surface of the valve of, say, $\frac{3}{4}$ in. in width, by almost the length of the valve, leaving the ends inside, then drill a little hole $\frac{1}{8}$in. at each end down into that place and put the valve in. The first time I tried that was four months ago, I think. When the engine went out from the shop the man who took her out says, 'She blows; I think we shall have to take these valves out and replace them.' So I had a new

set of valves, all fitted exactly every way, so as to just lift the cover off and replace those we had grooved out with the others.

After that I let the man run her on passenger trains. I put the air brake on her and put her into the hands of one of our very good runners, and ran a passenger train between Bloomington and Chicago—one of our heavy trains—and after he had run her two or three times he came to me and said, 'What in the world did you do to the valves of that engine? I used to run that engine before you put her in order on a freight, and she is an entirely different engine now; what did you do to the valves?' I said we did not do anything. 'Why certainly you have done something, for the engine don't handle as she used to handle.' Then I told him just what we had done—that we had cut those grooves, and he said the engine handled a great deal better and a great deal easier. He had run the engine previously a great deal, and he discovered it without knowing anything about what had been done, so that I rather came to the conclusion that there was really some merit in those grooves. The only difficulty there can be in it is this. At a certain point you may have what steam will blow through this ⅛in. hole down into the steam port. That may be a disadvantage, but there is only a certain time during the stroke of the engine that that can take place. During the other part of the stroke you have what steam goes through, and from this ⅞in. by 14in. or 15in. port, to lift up on the valve and take that much weight off the surface. I wanted to state this fact, and state what this engineer said abont it. On the strength of that experience I have put the same thing into three or four engines since with pretty good results. It has not been more than four months since the experiment began, so I cannot tell you what the result will be finally, but I simply suggest it to the Convention. It is a simple, easy thing to try, and any one can try it, for I do not think there is any patent on it."

It is not very easy to see why this groove gave good results, and we must rest content with Mr. Jackman's verdict. In our opinion, balancing valves will scarcely accomplish the required end in the case of locomotives; and inventors would do well to devote their attention to the production of some species of piston valve which will accomplish what is required. To produce such a valve under the conditions is not an easy task, but the success which has attended Mr. Beattie in dealing with outside cylinder engines may serve to stimulate others to grapple with engines with inside cylinders.

THE BEHAVIOR OF FLUID, WITH SPECIAL REFERENCE TO THE RESISTANCE OF SHIPS.*

From "Iron."

By the term "resistance" I mean the opposing force which a ship experiences in its progress through the water. Considering the immense aggregate amount of power expended in the propulsion of ships; or, in other words, in overcoming the resistance of ships, I trust you will look favorably on an attempt to elucidate the causes of this resistance. It is true that improved results in shipbuilding have been obtained through accumulated experience; but it unfortunately happens that many of the theories by which this experience is commonly interpreted, are interwoven with fundamental fallacies, which, passing for principles, lead to mischievous results when again applied beyond the limits of actual experience. The resistance experienced by ships is but a branch of the general question of the forces which act on a body moving through a fluid, and has within a comparatively recent period been placed in an entirely new light by what is commonly called the theory of stream-lines.

It is convenient to consider first the case of a completely submerged body

* A paper read before the Mechanical Section of the British Association by W. Froude, C. E.

moving in a straight line with uniform speed through an unlimited ocean of fluid. A fish in deep water, a submarine motive torpedo, a sounding-lead while descending through the water, if moving at uniform speed, are all examples of the case I am dealing with. It is a common but erroneous belief that a body thus moving experiences resistance to its onward motion by an increase of pressure on its head end, and a diminution of pressure on its tail end. It is thus supposed that the entire head end of the body has to keep on exerting pressure to drive the fluid out of the way, to force a passage for the body, and that the entire tail end has to keep on exerting a kind of suction on the fluid to induce it to close in again—that there is, in fact, what is termed plus pressure throughout the head end of the body and minus pressure or partial vacuum throughout the tail end.

This is not so; the resistance to the progress of the body is not due to these causes. The theory of stream-lines discloses to us the startling, but true proposition, that a submerged body, if moving at a uniform speed, through a perfect fluid, would encounter no resistance whatever. By a perfect fluid, I mean a fluid which is free from viscosity, or quasi-sodidity, and in which no friction is caused by the sliding of the particles of the fluid past one another, or past the surface of the body. The property which I describe as "quasi-solidity" must not be confused with that which persons have in their minds when they use the term "solid water." When the people in this sense speak of water as being "solid," they refer to the *sensation* of solidity experienced on striking the water-surface with the hand, or to the reaction encountered by an oar-blade or propeller. What I mean by "quasi-solidity," is the sort of stiffness which is conspicuous in tar or liquid mud; and this property undoubtedly exists in water, though in a very small degree. But the sensation of solid reaction which is encountered by the hand or the oar-blade, is not in any way due to this property, but to the *inertia* of the water: it is in effect this inertia which is erroneously termed solidity; and this inertia is possessed by the perfect fluid, with which we are going to deal, as fully as by water. Nevertheless, it is true, I am presently going to show you, that the perfect fluid would offer no resistance to a submerged body moving through it at a steady speed. It will be seen that the apparent contradiction in terms which I have just advanced is cleared up by the circumstance, that in the one case we are dealing with steady motion, and in the other case with the initiation of motion.

The proposition that the motion of a body through a perfect fluid is unresisted, or, what is the same thing, that the motion of a perfect fluid past a body has no tendency to push it in the direction in which the fluid is flowing, is a novel one to many persons; and to such it must seem extremely startling. It arises from a general principle of fluid motion, which I shall presently put before you in detail, namely, that to cause a perfect fluid to change its condition of flow in any manner whatever, and ultimately to return to its original condition of flow, does not require, nay, does not admit of, the expenditure of any power, whether the fluid be caused to flow in a curved path, as it must do in order to get round a stationary body which stands in its way, or to flow with altered speed, as it must do in order to get through the local contraction of channel which the presence of the stationary body practically creates. Power, it may indeed be said, is first expended, and force exerted to communicate certain motions to the fluid; but that same power will ultimately be given back, and the force counterbalanced, when the fluid yields up the motion which has been communicated to it, and returns to its original condition.

Assume a pipe bent, and its ends joined so as to form a complete circular ring, and the fluid within it running with velocity round the circle. This fluid, by centrifugal force, exercises a uniform outward pressure on every part of the uniform curve; and this is the only force the fluid can exert. This pressure tends to tear the ring asunder, and causes a uniform longitudinal tension on each part of the ring, in the same manner as the pressure within a cylindrical boiler makes a uniform tension on the shell of the boiler. Now, in the case of fluid running round within rings of various diameter, just as in the case of railway trains

running round curves of various diameter, if the velocity along the curve remain the same, the outward pressure on each part of the circumference is less, in proportion as the diameter becomes greater; but the circumferential tension of the pipe is in direct proportion to the pressure and to the diameter; and since the pressure has been shown to be inversely as the diameter, the tension for a given velocity will be the same, whatever be the diameter. Thus, if we take a ring of double diameter, if the velocity is unchanged, the outward pressure per lineal inch will be halved; but this halved pressure, acting with the double diameter, will give the same circumferential tension. Now this longitudinal tension is the same at every part of the ring; and if we cut out a piece of the ring and supply the longitudinal tension at the ends of the piece, by attaching two straight pipes to it tangentially, and if we maintain the flow of the fluid through it, the curved portion of the pipe will be under just the same strains as when it formed part of the complete ring. It will be subject merely to a longitudinal tension; and if the pipe thus formed be flexible, and fastened at the ends, the flow of fluid through it will not tend to disturb it in any way. Whatever be the diameter of the ring out of which the piece is assumed to be cut, and whatever be the length of the segment cut out of it, we have seen that the longitudinal tension will be the same if the fluid be moving at the same velocity; so that if we piece together any number of such bends of any lengths and any curvatures to form a pipe of any shape, such pipe, if flexible and fastened at the ends will not be disturbed by the flow of fluid through it; and the equilibrium of each portion and of the whole of the combined pipe will be satisfied by a uniform tension along it. Further, if the two ends of the pipe are in the same straight line, pointing away from one another, since the tensions on the ends of the pipes are equal and opposite, the flow of the fluid through it does not tend to push it bodily endways. This is the point which it was my object to prove; but in the course of this proof there has incidentally appeared the further proposition that a flexible, tortuous pipe, if fastened at the ends, will not tend to be disturbed in any way by the flow of fluid through it. This proposition may to some persons seem at first sight to be so paradoxical as to cast some doubt on the validity of the reasoning which has been used; but the proposition is nevertheless true, as can be proved by a closely analogous experiment, as follows:—Imagine the ends of the flexible tortuous pipe to be joined so as to form a closed figure; there will then be no need for the imaginary fastenings at the ends, since each end will supply the fastening to the other. Then substitute for the fluid flowing round the circuit of the pipe a flexible chain, running in the same path. In this case the centrifugal forces of the chain running in its curved path are similar to those of the fluid flowing in the pipe; and the longitudinal tension of the chain represents in every particular the longitudinal tension on the pipe. As a simple form of this experiment, if a chain be set rotating at a very high velocity over a pulley, it will be seen that the centrifugal forces do not tend to disturb the path of the running chain; and, indeed, the velocity being extremely great, the forces, in fact, tend to preserve the path of the chain in opposition to any disturbing cause. On the other hand, if by sufficient force we disturb it from its path, it tends to retain the new figure which has been thus imposed upon it. The stream of fluid in the tortuous flexible pipe would behave in a strictly analogous manner.

[Here the author clearly illustrated his propositions by means of elaborate diagrams.]

As streams approach a body, their first act is to broaden, and consequently to lose velocity, and therefore, as we know, to increase in quasi-hydrostatic pressure. Presently they again begin to narrow, and therefore quicken, and diminish in pressure, until they pass the middle of the body, by which time they have become narrower than in their original undisturbed condition, and consequently have a greater velocity and less pressure than the undisturbed fluid. After passing the middle they broaden again until they become broader than in their original condition, and therefore have less velocity and greater pressure than the undisturbed fluid. Finally, as

they recede from the body they narrow again, until they ultimately resume their original dimension, velocity, and pressure. Thus, taking the pressure of the surrounding undisturbed fluid as a standard, we have an excess of pressure at both the head and stern ends of the body, and a defect of pressure along the middle.

We will now consider what will be the result of substituting an ocean of water for an ocean of perfect fluid. The difference between the behavior of water and that of the theoretically perfect fluid is twofold, as follows :—First. The particles of water, unlike those of a perfect fluid, exert a drag or fractional resistance upon the surface of the body as they glide along it. This action is commonly termed surface-friction, or skin-friction ; and it is so well-known a cause of resistance that I need not say anything further on this point, except this, that it constitutes almost the whole of the resistance experienced by bodies of tolerably easy shape traveling under water at any reasonable speed. Secondly. The mutual frictional resistance experienced by the particles of water in moving past one another, combined with the almost imperceptible degree of viscosity which water possesses, somewhat hinders the necessary stream-line motions, alters their nice adjustment of pressures and velocities, and thus defeats the balance of stream-like forces and induces resistance.

This action, however, is imperceptible in forms of fairly easy shape. On the other hand, angular or very blunt features entail considerable resistance from this cause, because the stream-line distortions are in such cases abrupt, and degenerate into eddies, thus causing great difference of velocity between adjacent particles of water, and great consequent friction between them. "Dead water," in the wake of a ship with a full run, is an instance of this detrimental action.

So far we have dealt with submerged bodies only ; we will now take the case of a ship traveling at the surfaee of the water. But first, let us suppose the surface of the water to be covered with a sheet of rigid ice, and the ship cut off level with her water-line, so as to travel beneath the ice, floating, however, exactly in the same position as before. As the ship travels along, the stream-like motions will be the same as for a submerged body, of which the ship may be regarded as the lower half ; and the ship will move without resistance, except that due to surface-friction and mutual friction of the particles. The stream-like motions being the same in character as those we have been considering, we shall still have at each end an excess of pressure which will tend to force up the sheet of ice, and along the side we shall have defect of pressure tending to suck down the sheet of ice. If, now, we remove the ice, the water will obviously rise in level at each end, so that excess of hydrostatic head may afford the necessary reaction against the excess of pressure ; and the water will sink by the sides, so that defect of hydrostatic head may afford reaction against the defect of pressure. The hills and valleys thus formed in the water are, in a sense, waves ; and, though originating in the stream-like forces of the body, yet when originated, they come under the dominion of the ordinary laws of wave-motion, and, to a large extent, behave as independent waves. The consequences which result from this necessity are most intricate ; but the final upshot of all the different actions which take place is plainly this—that the ship in its passage along the surface of the water has to be continually supplying the waste of an attendant system of waves, which from the nature of their constitution as independent waves, are continually diffusing and transmitting themselves into the surrounding water, or, where they form what is called broken water, crumbling away into froth. Now, waves represent energy, or work done ; and therefore all the energy represented by the waves wasted from the system attending the ship, is so much work done by the propellers or tow-ropes which are urging the ship. So much wave-energy wasted per mile of travel, is so much work done per mile ; and so much work done per mile is so much resistance. The actions involved in this cause of resistance, which is sometimes termed "Wave-genesis," are so complicated that no extensive theoretical treatment of the subject can be usefully attempted. All that can be known about this subject must, for the

present, I believe, be sought by direct experiment.

Having thus briefly described the several elements of a ship's resistance, I will proceed to draw your attention more particularly to certain resulting considerations of practical importance. Do not, however, suppose that I shall venture on dictating to shipbuilders what sort of ships they ought to build; I have so little experience of the practical requirements of ship-owners, that it would be presumptuous in me to do so; and I could not venture to condemn any feature in a ship as a mistake, when, for all I know, it may be justified by some practical object of which I am ignorant. For these reasons, if I imply that some particular element of form is better than some other, it will be with the simple object of illustrating the application of principles, by following which it would be possible to design a ship of given displacement to go at given speed, with minimum resistance, in smooth water—in fact, to make the best performance in a "measured mile" trial.

I have pointed out that the cause of resistance to the motion of a ship through the water are:—first, surface-friction; secondly, mutual friction of the particles of water (and this is only practically felt when there are features sufficiently abrupt to cause eddies); and thirdly, wave-genesis. I have also shown that these are the only causes of resistance. I have shown that a submerged body, such as a fish, or torpedo, traveling in a perfect fluid, would experience no resistance at all; that in water it experiences practically no resistance but that due to surface-friction and the action of eddies; and that a ship at the surface experiences no resistance in addition to that due to these two causes, except that due to the waves she makes. I have done my best to make this clear; but there is an idea that there exists a form of resistance, a something expressed by the term "direct head-resistance," which is independent of the above-mentioned causes. This idea is so largely prevalent, of such long standing, and at first sight so plausible, that I am anxious not to leave any misunderstanding on the point.

Lest, then, I should not have made my meaning sufficiently clear, I say distinctly, that the notion of head-resistance, in any ordinary sense of the word, or the notion of any opposing force due to the inertia of the water on the area of the ship's way, a force acting upon and measured by the area of midship section is, from beginning to end, an entire delusion. No such force acts at all, or can act. No doubt, if two ships are of precisely similar design, the area of midship section may be used as a measure of the resistance, because it is a measure of the size of the ship; and if the ships were similar in every respect, so also would the length of the bowsprit, or the height of the mast, be a measure of resistance, and for just the same reason. But it is an utter mistake to suppose that any part of a ship's resistance is a direct effect of the inertia of the water which has to be displaced from the area of the ship's way. Indirectly the inertia causes resistance to a ship at the surface, because the pressure due to it makes waves. But to a submerged body, or to the submerged portion of a ship traveling beneath rigid ice no resistance whatever will be caused by the inertia of the water which is pushed aside. And this means that, if we compare two such submerged bodies, or two such submerged portions of ships traveling beneath the ice, as long as they are both of sufficiently easy shape not to cause eddies, the one which will make the least resistance is the one which has the least skin surface, though it have twice or thrice the area of midship section of the other.

The resistance of a ship, then, practically consists of three items—namely, surface-friction, eddy-resistance, and wave-resistance. Of these the first-named is, at least in the case of large ships, much the largest item. In the *Greyhound*, a bluff ship of 1100 tons, only 170 feet long, and having a thick stem and sternposts, thus making considerable eddy-resistance, and at ten knots visibly making large waves, the surface-friction was 58 per cent. of the whole resistance at that speed; and there can be no doubt that with the long iron ships now built, it must be a far greater proportion than that. Moreover, the *Greyhound* was a coppered ship, and most of the work of our iron ships has to be done when they are rather foul, which necessarily increases the surface-friction item. The second item of re-

sistance, namely, the formation of eddies, is, I believe, imperceptible in ships as finely formed as most modern iron steamships. Thick square-shaped stems and stern-posts are the most fruitful source of this kind of resistance. The third item is wave-resistance. On this point, as we have seen, the stream-line theory rather suggests tendencies, than supplies quantitative results, because, though it indicates the nature of the forces in which the waves originate, the laws of such wave-combinations are so very intricate that they do not enable us to predict what waves will actually be formed under any given conditions.

There are, however, some rules, I will not call them principles, which have to some extent been confirmed by experiment. At a speed dependent on her length and form, a ship makes a very large wave-resistance. At a speed not much lower than this, the wave-resistance is considerably less, and at low speeds it is insignificant. Lengthening the entrance and run of a ship tends to decrease the wave-resistance ; and it is better to have no parallel middle body, but to devote the entire length of the ship to the entrance and run, though in this case it be necessary to increase the midship section in order to get the same displacement in a given length. With a ship thus formed, with fair water-lines from end to end, the speed at which wave-resistance is accumulating most rapidly, is the speed of an ocean wave, the length of which, from crest to crest, is about that of the ship from end to end. I have said we may practically dismiss the item of eddy-resistance. The problem, then, to be solved in designing a ship of any given size, to go at a given speed with the least resistance, is to so form and proportion the ship that at the given speed the two main causes of resistance, namely, surface-friction and wave-resistance, when added together, may be a minimum. In order to reduce wave-resistance we should make the ship very long. On the other hand, to reduce the surface-friction we should make her comparatively short, so as to diminish the surface of wetted skin. Thus, as commonly happens in such problems, we are endeavoring to reconcile conflicting methods of improvement ; and to work out the problem in any given case, we require to know actual quantities. We have sufficient general data from which the skin-resistance can be determined by simple calculation; but the data for determining wave-resistance must be obtained by direct experiments upon different forms to ascertain its value for each form. Such experiments should be directed to determine the wave-resistance of all varieties of water-line, cross section, and proportion of length, breadth and depth, so as to give the comparative results of different forms as well as the absolute result for each.

PINE TIMBER.*

By Mr. C. GRAHAM SMITH.

From "Engineering."

Wood, which not a great time back was one of the principal materials of construction, has now been replaced to so great an extent by iron, that timber does not receive the attention from engineering students which it did in the youth of our older members.

Excepting for foundation piles, small roofs, and railway platforms, it is seldom employed in this country for what may be termed permanent engineering structures. Still, as many of us students will probably be engaged on work in new countries, the development of which is, to a great extent, dependent on a proper employment of its resources among which timber generally occupies a position by no means unimportant, and as this material is so highly appreciated by the contractor for staging, temporary bridges, and other appliances necessary in the carrying out of large engineering contracts, the author trusts his remarks may prove of value.

Where speed in execution is the point above all others to be attained, timber, unless in exceptional cases, is the material to employ ; for even in this country

* Read before the students of the Institution of Civil Engineers.

a wooden structure may be put up in the time occupied in rolling plates, and making templates for a more permanent one of iron.

Pine timber, one of the most abundant and useful of all woods, is found in one species or another nearly all over North America, and the countries bordering on, or in the vicinity of, the Baltic Sea.

Yellow, white, red and pitch pine, as also white and black spruce, are imported from North America ; that from the Baltic is invariably known as fir timber, and is usually named after the district or country in which it is grown.

The yellow and white pines of America, although botanically different, are, in practice, looked upon as the same timber. It is not considered so durable as the Baltic fir when exposed to the weather in this country, but in its native land it seems to answer well ; for the bridge over the Delaware at Trenton, was constructed with this timber in 1804, and the Pennsylvania Railroad Company have only now, seventy years after its erection, considered it advisable to replace it by an iron structure. A cargo of this timber will consist of balks varying in length from 20 ft. to 60 ft., and 40 to 80 cubic feet in content, the average scantling being about 16 in. by 16 in., and short logs may be had exceeding 26 in. by 26 in., but this is an exceptional size which commands a high price. If the balks composing a lot of this timber have an average content of 65 cubic feet, it may be bought at the market rate ; and if 1½ per cent. be added for each 5 ft. above 65 ft. and up to 80 cubic feet, a very fair approximation to the value of the wood will be obtained. It is much in request for pattern making, and other purposes requiring a soft, non-resinous, and easily worked wood ; and has a good quality of retaining its form when subjected to heavy working strains.

The red pine of America, so named from its color, is slightly harder than the yellow, and when exposed to damp is more durable. This, although an easily worked wood, is not used for such purposes as pattern making on account of its liability to twist and split, but when of good quality it is an excellent wood for masts and spars, being straight grained and tolerably free from knots. It is imported in balks up to 50 ft. in length, and generally about 40 cubic feet in content; the approximate extra value for each 5 ft. above this size is 1½ per cent. up to 50 cubic feet. The average scantling is 10 in. by 10 in., but it may be had in small quantities from 13 in. to 14 in. square.

Pitch pine, obtained from the Southern States of North America, is distinguished by the extremely large quantities of resin which it contains, and the distinctive character of its annual rings. In point of strength it is superior to yellow pine and Baltic fir to an extent of about 30 per cent., and is more durable than the former in positions subject to alternate wetness and dryness, but in a warm moist atmosphere it will very quickly rot ; when totally immersed in water or buried underground it is supposed to be surpassed in durability by Baltic fir, although its use in these positions is of too recent a date for this to be borne out by experience. On account of the large amount of resin which this wood contains it will not take paint, neither is it considered a nice wood to work ; for these reasons and on account of its dearness, it has not been much used excepting in the balk and by joiners for stairs and flooring boards. It is imported in balks averaging 16 in. × 16 in. and varying in length from 40 ft. to 70 ft. The market average is about 80 cubic feet, and the approximate extra value for each 5 ft. above this is 1½ per cent. up to 100 cubic feet ; but special sizes up to 150 cubic feet may be obtained at high prices. There now being large quantities in the market its price is considerably reduced, and it is consequently coming very much more into use.

American white and black spruce, distinguished by the color of its bark, is a species of white wood which forms a good tough material for temporary work; but should not be used in permanent situations, as it shrinks, warps, cracks, and is very liable to rot when exposed to warmth or damp. This timber is imported in deals which are used for joists in inferior houses, also in balks varying from 30 cubic feet to 50 cubic feet in content, but more frequently in unbarked round logs, 9 in. to 12 in. in diameter at the butt, and varying in length from 20 ft. to 50 ft. ; it is much used for ship

spars and other analogous purposes, in which case the bark is generally left on until the wood is cut up for use, this is said to preserve it from the rot and otherwise improve it ; but when exposed to the weather it will not last more than five or six years unless kept properly painted or varnished.

Baltic fir contains no small quantity of resin and is somewhat similar in appearance and texture to pitch pine. It is slightly stronger, tougher, and when used in this country more durable than American yellow pine. The color of this wood is dependent on the climate and soil in which it is grown, and varies from light yellow to red, but when named by color considerable ambiguity is caused, as in England it is designated either red or yellow according to local custom. It is an excellent material when employed in dry and well ventilated situations, or when completely underground or water ; still like most other woods it does not answer well in damp situations to which the air has access. Memel is considered to be the most durable of the whole pine class ; balks of this timber as well as those from Riga, Sweden and Norway, do not much exceed 14 in. × 14 in. × 40 ft. in length, but this size may be obtained at the market rate. The timber from the north-western provinces of Prussia, may be had from 18 in. to 20 in. square and 50 ft. in length without much additional cost ; but in order that there may be little sap wood and the logs be made as parallel as possible, it is usually cross cut into lengths varying from 20 ft. to 30 ft.

In newly sawn pine timber the sap and heart wood are generally very clearly defined; and when the balks are lying in the yard the quantity of sap wood may be roughly estimated in the early morning, as the dew will cause it to have a moist appearance whilst the more matured timber will be quite dry.

The Baltic spruce is not so tough as that obtained from America, but is generally considered to be more durable ; still there is little choice between them, both being equally unfit for any permanent work unless thoroughly seasoned and kept perfectly dry, but not warm. This timber is largely imported from Norway, and being often 45 ft. or more in length and only 8 in. or 9 in. in diameter at its thickest part, is extensively used for scaffold poles, ladders and mine props.

In the building trade there are certain favorite scantlings for joists, planks, roof spars, and other portions of a structure ; merchants, therefore, frequently ship a cargo of pine or spruce cut into planks, deals and battens of these sizes. Planks, deals and battens are usually 11 in., 9 in. and 7 in. in width respectively, by 2½ in. to 3 in. in thickness, and sometimes they are cut 4 in., but this is an exceptional size; although latterly many have been imported 6 in. thick and designated the "double deal." One great advantage to be derived from employing this foreign cut timber is that it is very much more seasoned than when imported in whole logs.

Many instance of wooden structures having stood centuries might be given, were it not well known that the durability of properly seasoned matured timber is beyond computation, when employed in those situations to which it is by nature adapted. Unfortunately the demand for timber is so great that it is felled at improper seasons, and consequently, on its arrival in this country, is often full of sap, and sometimes rot will be found to have set in; and this latter evil is not unfrequently propitiated after its arrival by its being stored on undrained waste ground fully exposed to the influence of this humid atmosphere, and so badly or closely piled that there is no ventilation whatever.

Trees for timber should be felled whilst the sap is not in circulation, that is a month or six weeks after they have begun to cast their foliage. Stripping the bark in the spring and felling the trees in the autumn or winter is stated by some authorities to harden the sap wood and make it firm and durable ; whilst others consider this treatment to shorten the life of timber, and render it very liable to rot. These remarks do not apply to pine timber, as it is an evergreen, and the circulation of the sap is still a point to be decided by botanists ; although practical men usually consider it to be less active during the winter months, when pine and fir are mostly felled; but so far as the author can learn this time is chosen merely on account of the convenience it affords for transport-

ing the timber to the banks of the freshets, sometimes a distance of 20 or 30 miles over marshy ground, which, unless frozen, would not sustain the weight of the horses.

In Australia the bushmen live in what are termed gunyahs; these are simply roughly formed huts covered with sheets of bark stripped from gum trees, the usual practice being to cut a ring of bark some 5 ft. or 6 ft. in height from the trunks of those trees nearest at hand; the tree dies, and the author can testify to the wood becoming hard and dry throughout in a very short space of time. This little piece of bush life has been introduced as giving matter for discussion, the process of "ringing" appearing to have, under some circumstances, sufficient merits to sanction its more extended application. If the bark be severed shortly after the leaves have begun to shoot they must depend for nourishment on the sap already within the tree, which, through the medium of the bark, will be more or less exhausted from all parts of the timber; whereas if the tree be stripped of its bark the wood will simply be dried by the influence of the atmosphere. This method will not answer with American pine, as the author has been informed that trees killed by this or other means, when left standing in that country, will, in the space of from 8 to 12 months, be full of worms, which seem to form directly under the bark.

Seasoning timber has from the earliest dates commanded much attention, and numerous methods have been proposed for superseding nature; among the principal of these are water seasoning, boiling and steaming. Water seasoning may be resorted to when dealing with small scantlings, but with large balks it is of little service, as the time occupied in penetrating to any depth is very considerable. Small timber treated in this way is not liable to warp or crack, the drying being carried on equally from the exterior to the interior; and as the timber is said to season more rapidly, timber ponds are considered by some to be necessary appendages to a timber yard. Most foreign pine wood undergoes this process to some extent, as when felled it is put into the freshets and carried by them to the rivers, where it is made into rafts sometimes four or five balks deep, and taken to a port for shipment, so being afloat from four to six months.

The time required for seasoning may be curtailed one-third by boiling or steaming, but this must not be carried to excess, or the strength and elasticity of the wood will be much reduced; it is not, therefore, considered advisable to continue the process longer than from 50 to 75 minutes for each inch in thickness, the exact time being determined by the nature of the wood. In shipbuilding this system is resorted to, as the timber when hot may be bent to almost any curve, and it is supposed to be a preventive against splitting, warping and the dry rot.

The generally accepted, although not fully determined, theory on which the success of these systems depends, is that the sap is dissolved, and thus a better circulation effected; and Mr. Sagismund Beer has found that this is greatly expedited by boiling the timber in a solution of borax, and afterwards washing it in hot water. Freshly imported timber of small size when treated by this process is fully shrunk, dried, and rendered, at the small cost of 4d. or 5d. per cubic foot, ready for use in the course of a few weeks; still it is to be feared that this method will not be found so efficacious when dealing with large scantlings, as the boiling is continued about six hours for each inch in thickness, whereby the elasticity of the exterior fibres of the timber must be impaired, and it is on these that the strength of wood mainly depends when used as struts and beams. It is said that these difficulties are got over by injecting the solution of borax under pressure, and as some experiments on large sizes of timber will probably be carried out under the author's supervision the results will be placed at the disposal of the Institution, even should these preconceived opinions prove erroneous.

Where time is not of first importance there is nothing like good dry fresh air for obtaining sound and durable timber; deals and planks are much sought after when seasoned under cover in this way.

The time occupied in seasoning timber depends so much on circumstances that it cannot be reduced to any rule of thumb; the same may be said of the weight lost during the process, which

varies with each species of timber and must not be taken at one-fifth or one-sixth as stated by some authorities; for instance pitch pine will not lose much more than one-fortieth of its weight, whilst English oak and yellow pine will sometimes be reduced as much as one-fourth.

Fresh air is also one of the best preventives against the rot; which is caused by the fermentation of the sap and is of two kinds. The "wet rot" caused by alternate wetness and dryness, and the "dry rot" by insufficient ventilation.

Many nostrums have been brought forward for its cure, but as they have proved of no practical use time will not now be taken up by referring to them; when once the rot sets in unless it be entirely cut away from the more sound timber the whole will be destroyed.

Nature in addition supplies other destroying elements, among which are sea-worms, and in tropical climates white ants, the latter of which have been known to honey-comb the sleepers at one end of a line of railway before the other was completed; but when the railway is once finished their ravages are at an end, for they will not attack timber subject to continuous vibration.

The most destructive sea-worms are the *Teredo navalis* and the *Limnoria terebans*; the former species, which is commonly known as the ship-worm, seems to be a development of the vegetation which attaches itself to timber, for it enters the wood by the smallest possible hole and remains therein, increasing in size as it proceeds; it is often found the length of one's finger, and it is said to have reached 3 ft. in length and ¾ in. in diameter. The latter species consists of small creatures seldom more than ⅛ in. in length, still they do fully as much mischief as their larger companions. From the experiments of Mr. Stevenson at the "Bell Rock," it would appear that all kinds of pine wood are completely destroyed by the *Limnora terebans* in periods of time varying from one and a half to four and a half years.

"Kyanizing," "Burnetizing," "Creosoting," and other methods have been adopted for preserving timber; but as creosoting is now generally employed, to the exclusion of the other more expensive processes, in most situations not especially liable to fire or where its odor is not objectionable, it will alone here be considered. Timber to be creosoted is put into large iron cylinders in which a vacuum is maintained for a period governed by the quality, scantling and condition of the wood; by this means the sap is withdrawn, when its place is supplied by creosote, extracted from coal tar, in which it exists to the extent of from 20 to 23 per cent.; this is forced into the pores of the timber under a pressure of from 100 lb. to 180 lb. per square inch. Yellow pine may be impregnated with 12 or more pounds of creosote per cubic foot, but 10 lb. is the quantity usually specified; and in order to get thorough work all timber should be weighed both before and after the operation. Nominal creosoting is practiced to no little extent; the vacuum is often left on for too short a time, or perhaps not put on at all, the wood is consequently creosoted only ¾ in., or an inch in depth from the surface; and should it not be properly seasoned, sap is confined to the interior and the wood rendered most liable to decay. This has in fact much the same effect as painting, smoking, or charring, none of which should be resorted to until the wood is thoroughly seasoned; it is often desirable to leave posts or framed structures exposed to the weather for a year or more before painting them. Creosoting pine timber with 10 lb. per cubic foot costs, without including wear and tear of plant, about 5½d. per cubic foot; it reduces its transverse strength fully one-eighth, but at the same time renders it very durable and protects it to a great extent against the white ant and sea-worms; but for what length of time timber thus prepared will stand the attacks of the latter, has not yet been definitely determined. Mr. Stevenson states that at Invergordon and other places the worm eats freely thoroughly creosoted timber; but at Ostend creosoted timber was at the end of seven years untouched, whilst that uncreosoted, but otherwise under precisely similar circumstances, was completely perforated by the *Teredo* in two years; and many like instances might be given. Mr. Rendal, in giving evidence before the Leith Harbor Commissioners, limits the life of creosoted timber submerged in that port to 20 years;

if this be so a step in the right direction has been made, for Mr. Stevenson found that the *Limnoria terebans* began to attack even greenheart when submerged nineteen years; and at Wick Harbor and Salem in the Sound of Mull this timber was found to be attacked after being submerged only four years.

Galileo was among the first to investigate the strength of wooden beams on purely mathematical principles; and, like many later investigators, after employing the higher mathematics to an unlimited extent, arrived at conclusions incompatible with practice. To use Tredgold's words, "fortunately that precision so essential to the philosopher is not absolutely necessary to the architect and engineer," consequently simple formulæ, such as $W = C\frac{b\,d^2}{L}$, may be resorted to in practice. These formulæ are generally deduced from actual experiment in the manner somewhat as follows: If a beam of b inches in breadth, d inches in depth, and L feet clear span, breaks with a weight W in cwts. applied at the centre, it is not difficult to determine in what ratio the strength of another beam of the same material will vary; if the breadth be double it is at once evident that its strength is doubled, if its length be double its strength is practically halved, and if its depth be double its strength will be increased four times; for these reasons the sectional areas in tension and compression, as well as the distance apart of their centres of gravity are doubled, consequently the moment of resistance of the beam is increased four times, and similarly by using any other depth it will be found that this moment varies as the square of the depth. The breaking weight, therefore, varies directly as the breadth and square of the depth, and inversely as the length, therefore $W \propto \frac{b\,d^2}{L}$. Now it is well known that the adhesion of the particles or fibres to one another affect the strength of a beam, to an extent which can only be determined by introducing an unknown quantity; W therefore becomes equal to $C\frac{b\,d^2}{L}$, where C is the unknown, but nearly constant, quantity, the value of which can be ascertained only by actual experiment. But since the strengths of no two beams of the same timber and scantlings are precisely the same, it follows that no two constants will be equal in value; this accounts, to some extent, for the variety of scantlings employed for one and the same purpose. A short time since a warehouse floor gave way, and the engineers employed on opposite sides of the law action which ensued had little difficulty, by using the extremes of constants, in making their calculations suit the wishes of their respective clients. The floor was thus shown on good authority to be at the same time both amply strong and too weak; under these circumstances the only course to pursue was to call in an independent witness, who not being content to accept a constant which might at any time be disputed, had a beam from the floor in question tested, deduced a constant from the result, and gave his evidence accordingly. As the quality of timber varies very considerably, even in the same cargo, before employing it in work of any magnitude, one or more average samples should be tested, and a constant deduced on which all calculations for the strength of the timber may be based, This method is pursued by Mr. Lyster. engineer-in-chief to the Mersey Docks, and Harbor Board; and as it has been his practice for many years past, he is now in possession of some very valuable results, a few of which, by his kind permission, are put before you in the Addenda.

The experiments given have been selected on account of their being, so far as the author can learn, the largest scantlings ever tested. The constants of Tredgold, Barlow, and others were obtained by testing small pieces of timber, in selecting which it has evidently gone against the conscience of the investigators to take those cross-grained and containing knots; but timber of any size has always more or less of these blemishes, consequently their constants give a strength to timber which cannot be attained in actual work. On referring to the Addenda it will be found that (Experiment No I.) a best selected Memel fir beam 13½ in. by 13½ in. with 10 ft. 6 in. clear span practically gave way with a distributed load of 56 tons,

and finally broke down with 61 tons; whilst the distributing breaking weight of this beam found by employing the constant for Memel given by Tredgold is 114 tons, and by that of Barlow 120 tons; similar results will be obtained if the remaining experiments be compared with the same or other authorities.

Constants deduced from testing large pieces of timber will be found in the Addenda, and it is the author's opinion that these will give results approximating very closely to ordinary practice; should this meeting take a similar view there will be little difficulty in deducing from them other constants for beams loaded or supported in any way whatever; or even for columns which are of such proportions that they give way wholly by flexure.

The deflection of timber which is to be used in a permanent structure need hardly be considered, so long as factors of safety of eight or ten are adhered to, for up to one-fifth of the breaking load it is certainly not excessive.

In conclusion it may be well to state that the author has based his remarks mostly on experience gained whilst studying under Mr. Lyster; and he hopes they will harmonize with those of his fellow-students.

Addenda.

The accuracy of the following results is beyond question; for the experiments were carried out in accordance with instruction from the engineer to the Mersey Dock Board under the supervision of the resident engineer at Birkenhead.

The tests by hydraulic machinery were made at the Birkenhead Chain Test Works belonging to the Dock Board. This machinery is so arranged that it is checked by three separate and independent appliances, all of which were accurately adjusted. Firstly, by a lever and dial, the lever being actuated by a small metal ram worked direct from the pressure on the cylinders of the strain being registered on the dial. Secondly, by dead weights lifted by a small ram which is also worked direct from the pressure in the cylinders. And lastly, by dead weighted levers working on knife edge centres up to 100 tons. The machinery was constructed by Sir William Armstrong and Co., and is fully up to their usual standard of workmanship.

The constants deduced or given are intended to be employed in the formula $W=\frac{C\,b\,d^2}{L}$ where W = the breaking weight at centre in cwts., b=breadth in inches, d=depth in inches, and L=clear span.

No. I.

Experiment with two best selected Memel fir beams 13½ in. wide, 13½ in. deep, and 10 ft. 6 in. clear span. Both beams were cut from the same balk and placed 12 ft. apart centre to centre, the space between them being bridged with railway metals, upon which pig iron was loaded until the beams broke.

The following observations were taken:

Load Distributed on the Two Beams.	Deflection.		Remarks.
	Beam cut from Butt.	Beam cut from Top.	
Tons.	In.	In.	
40.2	.10	.12	
59.6	.31	.27	
75.2	.37	.51	
97.3	1.12	1.45	First fracture observed.
111.7	..	..	The deflection not taken as the beams had crushed at ends.
122.0	Broke.	Broke.	

The distributed breaking load on each of the above beams is, therefore, $\frac{122}{2}=61$ tons, which is equivalent to 30.5 tons applied at the centre.

$$C=\frac{W\,L}{b\,d^2}$$

$$=\frac{30.5\times20\times10.5}{13.5\times13.5\times13.5}=\frac{6405}{2460}$$

Therefore $C=2.60$.

No. II.

Experiment with two Quebec yellow pine beams 14 in. wide, 15 in. deep, and 10 ft. 6 in. clear space. Both beams were cut from the same log and tested in precisely the same manner as No. I.

The following observations were taken:

SUMMARY OF TIMBER EXPERIMENTS NOS. I. TO V.

Species of Timber.	Scantling.	Clear Span.	Number of Beams Tested.	Average Break-load applied at Centre.	Average valve of C in $W = C\frac{bd}{L}$.	Remarks.
	In. In.	Ft. In.		Tons.		
Baltic Memel fir.....	$13\frac{1}{2} \times 13\frac{1}{2}$	10 6	2	30.50	2.60	Distributed Load.
Quebec yellow pine..	14 ×15	10 6	2	30.50	2.03	" "
Baltic fir (average)...	6 ×12	12 3	2	9.50	2.70	Load applied at centre by means of hydraulic machinery.
Pitch pine..........	6 ×12	12 3	2	10.35	2.93	
American red pine...	6 ×12	12 3	2	8.00	2.27	
Pitch pine.........	14 ×15	10 6	2	60.00	4.00	
Quebec yellow pine..	14 ×15	10 6	2	36.00	2.40	

Load Distributed on the Two Beams.	Deflection. Practically the same on both Beams.	Remarks.
Tons.	Inches.	
26.6	.18	
57.0	.29	
69.6	.39	
83.0	.66	
102.0	.87	First fracture observ'd
122.0	Broke.	

The beam cut from the top end of the log broke down bodily.

The distributed breaking load on each of the beams is, therefore, $\frac{122}{2} = 61$ tons, which is equivalent to 30.5 tons applied at the centre.

$$C = \frac{W\,L}{b\,d^2}$$

$$= \frac{30.5 \times 20 \times 10.5}{14 \times 15 \times 15} = \frac{6404}{3150}$$

Therefore $C = 2.03$.

No. III.

Experiment to ascertain the relative strength of Baltic fir, pitch pine, and American red pine. Beams 6 in. wide, 12 in. deep, and 12 ft. 3 in. clear bearing. The ends of the logs were placed in stirrups, and the load applied at the centre by means of hydraulic machinery.

The following observations were taken:

Load applied at Centre.	Baltic Fir. Deflection.		Pitch Pine. Deflection.		Red Pine. Deflection.	
	Sample No. 1.	Sample No. 2.	Sample No. 1.	Sample No. 2.	Sample No. 1.	Sample No. 2.
Tons	In.	In.	In.	In.	In.	In.
3.0	.29	.37	.11	.38	.43	.37
5.0	.56	.60	.28	.61	.70	.61
7.5	..	..	..	..	Broke	
8.0	.87	1.11	.53	.97	..	1.94
8.5	Broke	..	..	..	..	Broke
10.0	..	1.93	.78	1.31		
10.2	..	..	Broke			
10.5	..	Broke	..	Broke		

Baltic Fir.—Average breaking weight applied at centre

$$= \frac{8.5 + 10.5}{2} = 9.5 \text{ tons.} \quad C = \frac{W\,L}{b\,d^2}$$

Therefore

$$C = \frac{9.5 \times 20 \times 12.25}{6 \times 12 \times 12} = \frac{2327}{864} = 2.70.$$

Pitch Pine.—Average breaking weight applied at centre

$$= \frac{10.2 + 10.5}{2} = 10.35 \text{ tons.}$$

Therefore

$$C = \frac{10.35 \times 20 \times 12.25}{6 \times 12 \times 12} = \frac{2536}{864} = 2.93.$$

American Red Pine.—Average breaking weight applied at centre

$$\frac{7.5 + 8.5}{2} = 8 \text{ tons.}$$

$$\text{Therefore } C=\frac{8\times20\times12.25}{6\times12\times12}=\frac{1960}{864}=2.27.$$

No. IV.

Experiment with two pitch pine beams cut from the same log 14 in. wide, 15 in. deep, and 10 ft. 6 in. clear bearing. Tested by hydraulic machinery in the same manner as No. III.

The following observations were taken:

Load applied at Centre.	Deflection.		Remarks.
	Beam cut from Butt.	Beam cut from Top.	
Tons.	Inches.	Inches.	
10.0	.02	.05	
20.0	.22	.27	
30.0	.36	.41	
40.0	.49	.61	
50.0	.72	.93	
59.2	..	Broke.	
60.0	1.14		

In testing the beam cut from the butt of the log, the strain was slacked off at 60 tons, and on account of being again put on rather too suddenly the beam broke with 57.5 tons, but there can be very little doubt but that 60 tons is very near the breaking weight of the specimen.

$$C=\frac{W\,L}{b\,d^2}$$

$$=\frac{60\times20\times10.5}{14\times15\times15}=\frac{12{,}600}{3150}$$

Therefore $C=4$.

No. V.

Experiment with two Quebec yellow pine beams, cut from different logs, 14 in. wide, 15 in. deep, and 10 ft. 6 in. clear span. Tested by hydraulic machinery in the same manner as No. III.

The following observations were taken:

Load applied at centre.	Deflection.		Remarks.
	Sample No. 1.	Sample No. 2.	
Tons.	Inches.		Deflection of sample No. 2 not taken.
10.0	.14		
20.0	.44		
30.0	.56		
34.0	..	Broke.	
38.3	Broke.		

Average breaking weight applied at centre

$$=\frac{38.3+34}{2}=36 \text{ tons.}$$

$$C=\frac{W\,L}{b\,d^2}$$

$$=\frac{36\times20\times10.5}{14\times15\times15}=\frac{7560}{3150}$$

Therefore $C=2.40$.

From a careful study of many experiments on both large and small scantlings of timber, and taking into consideration that sap wood is generally more or less present in most beams, the author would advise that the following constants be employed in ordinary work: Baltic fir when of best quality 2.6, when second rate 2.3; Canadian yellow pine 2.2; pitch pine 2.4; and American red pine 2.3.

TELFORD AND MACADAM ROADWAY PAVEMENT.

By A. P. STORRS, Jr., C. E.

Written for Van Nostrand's Engineering Magazine.

In the construction of a Telford and Macadam Roadway Pavement, the first consideration must be given to the selection of the materials which are to be used. This is a question of the greatest importance, for with poor materials it is impossible to construct a good and durable pavement. The location of the proposed work must decide which of the different materials of which it is proper to construct such a pavement may be used. The hardest and most durable rock that can be procured without too large an expense is always the most desirable.

MATERIALS.

For the "Telford" foundation, any

rock which is not too easily crushed or decomposed by the action of water, may be used. Of those which are found most common, trap rock and gneiss are the best adapted to this use; they are easily sledged to the required shape and size, and are very durable. A few weeks since, a Telford pavement of this material, which had been in use for five years, was examined, and not the least signs of decomposition could be discovered.

For broken stone, or Macadam, or road metal, as it is sometimes called, a *hard* and *tough* material is required, such as green stone, trap rock, hard lime stone, or slag from iron furnaces.

For the surfacing or binding of the Macadam, clean sharp gravel or the screenings of the broken stone may be used. The latter can be surfaced with less rolling, and retains moisture for a longer time when sprinkled, and, therefore, has the preference.

CROSS SECTION.

Before the materials selected for the pavement can be prepared, the *cross section* of the pavement must be decided upon. This must be governed by the kind and amount of traffic it is required to carry. If this is constant and heavy, a thick pavement is reqired; if there is to be but little travel over it, as upon a country road, a much thinner pavement will be all that is necessary.

For city use, where the traffic is heavy, a Telford foundation 8 inches in thickness is laid, and covered with 10 inches of broken stone. Telford, on the Holyhead roads in England, laid upon a level road had a foundation of from 4 to 7 inches in thickness, placing the smaller stones at the side or gutter, and the larger ones in the centre, thus giving the surface a crown from the gutter to the centre. In Germany, upon the Government roads, the foundation is laid from 8 to 12 inches in thickness, and when the pavement is laid across marsh lands, two courses of foundation are laid, one upon the other, each of them 12 inches in thickness, and upon this the road metal is placed.

For an ordinary highway or turnpike, a Telford foundation 6 inches thick, with 6 inches of Macadam upon it, thoroughly rolled and surfaced, affords a perfect protection to the road bed, and is therefore all that is required.

In all cases, whatever may be the thickness of the pavement laid, the surface must be so formed, that the water falling upon it will run to either side, when it will be conducted by the gutter to the side drains or sewers, and by them removed from the road. If this crown is too great, the water flowing across the pavement rapidly will form gutters and destroy the surface; this must be carefully avoided. A crown of 1 in 60 for a pavement over 60 feet in width, and 1 in 30 for one of less width, will be found suitable. Upon a steep grade a *larger crown* is required than upon a light one, to prevent the surface water from flowing too far down the grade and over the surface of the road, before reaching the gutter. The crown should take the form of the arc of a circle. Experience has shown, that when the surface of a pavement is made to pitch in a straight line from the centre of the roadway to either gutter, that passing vehicles are inclined to keep near the gutter, and by constant use this portion of the road is worn down more rapidly than the rest, and a hollow is formed in the surface which retains the water, and prevents it from flowing into the gutter; and causes it to take a new channel for itself in the roadway.

ROAD BED.

Like any other structure, a pavement must have a firm foundation upon which to rest, or it will be worthless. The road bed must be carefully prepared; all rock must be removed to a sufficient depth to allow 6 inches of earth between it and the Telford. All boulders which appear on the surface must be removed, and the holes thus made filled with earth and well rammed. Any soft loam or decayed vegetable matter should be replaced by good firm material. The road bed should be shaped to the crown which the pavement will have when completed, and the whole surface well rolled with an iron road roller, of not less than two tons in weight, drawn by horses.

Care must be taken to drain the road bed thoroughly, so that neither natural springs nor surface water shall cause the earth of which it is formed to become soft or spongy. The road bed should be

raised from 2 to 4 inches above the required grade (after making allowance for the thickness of the pavement) to allow for settlement caused by the heavy rollers, with which the Macadam is rolled, forcing the Telford into the road bed, and the packing of the materials of which it is formed.

TELFORD FOUNDATION.

Upon the road bed is laid the Telford foundation. This may be constructed of any good firm rock, which may be convenient to the work and easily procured. The material used in New York City for this purpose is gneiss rock, which is found in large quantities upon the island. Its abundance and consequent cheapness recommend it ; and experience has proved it to be equal to any kind of stone for a foundation. Care is taken to select a quality that does not contain too much mica, and which is firm and sound.

The rock which has been selected for the foundation or "Telford," is broken with sledges to the required size. The rule is that the stones should have a base of not more than 80 or less than 12 square inches, and a depth of a little more than the required thickness of the foundation when completed. These stones are set in courses with their bases on the road bed and their greatest length extending across, and at right angles to the centre line of the road. The ends of each stone are clipped square so as to present as great a surface as possible to the adjoining stones, in order to form as strong a bond as possible. Each course must be laid so as to break joints with the one laid before it ; the stones must be set plumb, rather than at right angles to the grade line; this is done so that the weight of passing vehicles may be received and transferred to the road bed, without forcing the stones from their positions.

The pavement is then thoroughly wedged by forcing small pieces of stone into all the interstices. This is done with an iron bar about 4 feet long and 1½ inch in diameter, which is furnished with a wedge shape point, and a round flat head about 2½ inches in diameter. With the point of the bar the stones are forced apart, and into the spaces thus formed smaller stones are driven with the head of the bar. When this wedging is done thoroughly, a good foundation for the Macadam is secured. Any projecting points are then removed from the surface of the "Telford," by breaking them off with a small hand hammer; this is called clipping. Any loose stone remaining upon the surface, are either removed or broken to about the size of the Macadam, which is to be placed upon the road.

The object of this foundation is twofold. 1st, It is the means of distributing the weight or pressure which is applied to the surface of the road, over a large area of road bed, and thus preventing any possibility of the pavement sinking and becoming uneven. 2d, It serves as a drain for any water that would otherwise collect under the pavement, and prevents it from softening or otherwise injuring the road bed.

MACADAM OR ROAD METAL.

This "Telford foundation" is covered with broken stone, called "Macadam" or "road metal," to a thickness of from 6 to 12 inches. This course receives all of the wear caused by the traffic, and defective construction here will increase very largely the amount of labor and materials required to keep the road in repair, and the greatest care must be exercised in the selection of the material and the manner in which they are applied. The road metal must be made of a tough and hard substance. Basaltic and trap rocks, and especially those which contain a large percentage of hornblende are the best.

Neither granite, nor any rock which contains quartz, feldspar or mica, in any considerable quantities, should be used. They are easily crushed, and such as contain feldspar are soon decomposed by the action of the weather.

The greater the specific gravity, the firmer the grain, and in trap rocks, the more decidedly blue the color, the tougher and more durable is the rock.

When trap rock has a coarse grain and is of a brownish color, it will crush easily, and decay when exposed to the action of the weather. More or less of this material is found upon the surface of all beds of trap rock, but should never be used for metaling a road.

The rock selected is broken by hand or machine to the required size. In this

city the specifications are as follows:

"The stone to be of trap rock, of a sound, hard and durable quality, entirely free from soft, disintegrated, or other stone that can be easily crushed, to be broken to a uniform size, so as to pass through a ring of from 1½ inches to 2 inches in diameter, and to be screened free from dust and dirt."

Macadam required that "all stones should be broken by hand into angular fragments." When a large quantity of stone is to be used, it is almost impossible to get it broken by hand to the required size as rapidly as it is wanted.

To make it profitable, the men employed must be paid by the yard, and in order to increase their wages they will leave the stone too large. Nearly all of the broken stone used in this city, is broken from the spawls taken from the "Trap Block" quarries on the west of the Hudson River opposite the city.

Machines now in use, known as the "Improved Blake Crushers," break the rock into "angular fragments" sufficiently uniform, and to any desired size.

Hand broken stone require less rolling to pack them than machine broken stone, but when once packed they make equally durable pavements.

All hand broken stones should be handled with forks made for the purpose, before they are placed upon the road, in order to free them from dirt and dust.

Machine broken stones should be passed over a scum to separate from them all dust and fine stone, which is formed in the breaking. This fine material or "scummings" may be used to advantage for the binding or surfacing of the road.

The broken stone is spread upon the Telford foundation in two layers or courses of from 3 to 6 inches in thickness. The first layer is rolled until it ceases to settle, and is firm as the roller passes over it. The second layer is then added and rolled until it presents a smooth surface.

On the first Telford and Macadamized roads built in this city, broken stone of gneiss was used for the first layer, but it proved to be as expensive as trap, and was much inferior to it. When the second layer was rolled the soft stone beneath would crush to a powder. The use of it has since been discontinued.

Two layers of broken trap, each 6 inches in thickness, make, when rolled, nearly a solid mass 10 inches in thickness, making with the Telford foundation, as laid in New York, a pavement 18 inches in thickness, which is nearly impervious to water, and is not disturbed by frost. The frost often penetrates the earth for some distance below the bottom of the pavement, but it never heaves it.

During the present winter (1874 and 1875), I made an examination of a number of different pieces of this pavement, and found in every case that the frost had penetrated the road bed for a depth of from 9 to 18 inches, and that the interstices in the Telford foundation were filled with ice, but in not a single instance was the pavement disturbed by the frost coming out of the ground.

The rolling of the broken stone, and the furnishing of the surface, is done with heavy iron rollers moved by either steam or horse-power.

A sufficient number of sprinkling carts are provided to keep the stones thoroughly wet during the process of rolling. This causes them to pack more rapidly than when they are dry.

SURFACING AND ROLLING.

When the second layer of broken stone has been rolled so that it presents a smooth surface, *it is thoroughly wet*, and a thin layer, about one-half an inch in thickness of clean sharp gravel, or what is preferable, screenings and clips of trap rock, is spread over it, and rolled, a second layer is spread of the same material, and so on, until the water from the carts ceases to penetrate the pavement, but is held up on the surface, or, in other words, the surface is "puddled."

During all of this process of rolling, the pavement must be kept thoroughly saturated with water. When the surface is puddled the heavy rollers are removed, and a road roller, weighing two tons, which is drawn by horses, keeps the surface smooth until it is thoroughly dry. The road is then ready to be thrown open to traffic.

Where the grades are not greater than 1 in 15, steam rollers made by Aveling & Porter, England, are generally used on the city work—these weigh about 15 tons. On any grade over 1 in 15, large

iron rollers, weighing about 8 tons, and drawn by 8 horses, are used.

DRAINING.

Drains or receiving basins should be built at a distance of not more than 300 feet apart, to take the water which is collected in the gutters away from the road.

When this cannot be done, and the water has to be carried a greater distance by the gutter, or when the grade is greater than 1 in 40, concrete gutters should be laid. For this purpose, 1 part cement, 2 parts clean sharp sand, and 6 parts clean broken stone, are mixed together. Sufficient water is then added to bring the mass to a proper consistency.

The Macadam is removed for a distance of 2 feet from the curb, to a depth of 6 inches, the trench thus formed is thoroughly wet, and filled with the concrete, which is settled with a wooden rammer until it is flushed. This forms a gutter which cannot be washed away by the water, and adds but a very small amount to the cost of the road, and will save a great deal both in maintenance and repairs.

When no curb is laid at the sides of the roadway, a gutter made of trap block or cobble stones is desirable, this prevents any portion of the pavement from working out to the sides of the road.

MAINTENANCE.

A Telford and Macadam road must be properly "maintained" or "kept up." If this is done thoroughly from the start the cost of repairs of the road will be very much reduced. In fact, a road that is well and thoroughly maintained, needs very little repairing, for it is never out of order.

Fresh materials must be added in small quantities, as they are needed, to keep the road to its proper cross section. Any small holes, ruts, loose stone, or other imperfections must be filled or removed; this requires the constant care of industrious and trusty men.

A road should be divided into sections of not more than a quarter of a mile in length. At or about the centre of each section should be a small quantity of broken stone and gravel, to be used as it is required upon the section; and also a place where all droppings, or other material taken from the surface of the road, may be deposited.

One man can take care of from four to twelve such sections. The number depends upon the width of the road and the amount of traffic over it.

When a pavement is new, small stones will "prick up." These must be removed, and the hole formed filled with gravel. Any accumulation of mud or dust must be removed by scraping. This can be done just after a shower, when the road is wet, to the best advantage. The road must not be scraped too clean, a covering of $\frac{1}{4}$ inch in thickness of the dust which is formed by the wear of the road metal protects the surface of the pavement, and when it is kept moist, as it should be, makes the road smoother for the passing vehicles, and less trying to the horses driven over it.

When the stones of which the pavement is composed become bare, a very thin layer of clean sharp gravel should be spread over it. It is not necessary to roll this, the wheels of passing vehicles soon form it into a smooth surface. When it becomes necessary to raise the road, to its original cross section, the surface should be "raised" with short picks, so that new material placed upon it will when rolled form a perfect bond with the old material.

The rolling is best done with heavy rollers, but if these are not convenient, the action of the wheels passing over the thin coat of stone will in time serve the same purpose. The surface of the road must be kept moist, but not wet, if it becomes too dry the stones lose their bond, and the road becomes rough; and too much water will soften the surface, and in time will form ruts. Both of these evils must be carefully avoided.

The following data are the result of careful experiments, and will be of great value and convenience in making estimates for, or in the construction and maintenance of, a Telford and Macadamized roadway pavement:

One man's labor for 10 hours is equivalent to the following items:

2 cubic yards of stone sledged for Telford pavement.

8 cubic yards of stone loaded and unloaded from wagon.

35 square yards 8 in. Telford pavement laid.
31 square yards 8 in. Telford pavement wedged.
60 square yards 8 in. Telford pavement clipped.
$1\frac{1}{2}$ to 2 cubic yards trap rock broken from quarry spawls.
16 cubic yards broken stone or gravel spread on road.

A gang of men for paving Telford pavement should be devised as follows :

1 man paving to every 6 ft. in width of pavement.
1 man wedging to every 5 ft. in width of pavement.
1 man clipping to every 10 feet in width of pavement.

A steam roller requires

1 steam engineer.
1 laborer or wheelman.
1 water cart.
1 watchman.

Aveling & Porter's 15 ton road roller will consume per day :

$\frac{1}{3}$ to $\frac{1}{2}$ ton of coal.
$\frac{1}{10}$ gal. oil.
$\frac{2}{10}$ lbs. cotton waste.

Will roll and finish 151 square yards pavement.

Each steam roller should be attended by :

2 sprinkling carts.
3 road men to keep the surface of the road to the required shape, and to spread gravel.

Maintenance :

1 2-horse monitor will sprinkle in the city, when water is convenient, 32,000 square yards road.
1 1-horse cart will sprinkle 14,000 square yards.
1 man will keep 30,000 square yards of pavement free from stones and droppings where the travel is constant.

THE ORIGIN AND GROWTH OF ENGINEERING SCIENCE.

Inaugural Address of SIR JOHN HAWKSHAW, F. R. S., before the British Association.

Condensed from report in "Nature."

To those on whom the British Association confers the honor of presiding over its meetings, the choice of a subject presents some difficulty.

The Presidents of Sections, at each annual meeting, give an account of what is new in their respective departments ; and essays on science in general, though desirable and interesting in the earlier years of the Association, would be less appropriate.

Past Presidents have already discoursed on many subjects, on things organic and inorganic, on the mind and on things perhaps beyond the reach of mind, and I have arrived at the conclusion that humbler themes will not be out of place on this occasion.

I propose in this Address to say something of a profession to which my lifetime has been devoted—a theme which cannot perhaps be expected to stand as high in your estimation as in my own, and I may have some difficulty in making it interesting ; but I have chosen it because it is a subject I ought to understand better than any other. I propose to say something on its origin, its work, and kindred topics.

Rapid as has been the growth of knowledge and skill as applied to the art of the engineer during the last century, we must, if we would trace its origin, seek far back among the earliest evidences of civilization.

In early times, when settled communities were few and isolated, the opportunities for the interchange of knowledge were scanty or wanting altogether. Often the slowly accumulated results of the experience of the wisest heads and the most skillful hands of a community were lost on its downfall. Inventions of one period were lost and found again. Many a patient investigator has puzzled his brain in trying to solve a problem which had yielded to a more fortunate

laborer in the same field some centuries before.

The ancient Egyptians had a knowledge of Metallurgy, much of which was lost during the years of decline which followed the golden age of their civilization. The art of casting bronze over iron was known to the Assyrians, though it has only lately been introduced into modern metallurgy; and patents were granted in 1609 for processes connected with the manufacture of glass, which had been practised centuries before. An inventor in the reign of Tiberius devised a method of producing flexible glass, but the manufactory of the artist was totally destroyed, we are told, in order to prevent the manufacture of copper, silver, and gold from becoming depreciated.

Again and again engineers as well as others have made mistakes from not knowing what those had done who have gone before them, and have had the same difficulties to contend with. In the long discussion which took place as to the practicability of making the Suez Canal, an early objection was brought against it that there was a difference of 32½ feet between the level of the Red Sea and that of the Mediterranean. Laplace at once declared that such could not be the case, for the mean level of the sea was the same on all parts of the globe. Centuries before the time of Laplace the same objection had been raised against a project for joining the waters of these two seas. According to the old Greek and Roman historians, it was a fear of flooding Egypt with the waters of the Red Sea that made Darius, and in later times again Ptolemy, hesitate to open the canal between Suez and the Nile. Yet this canal was made, and was in use some centuries before the time of Darius.

Strabo tells us that the same objection that the adjoining seas were of different levels, was made by his engineers to Demetrius, who wished to cut a canal through the Isthmus of Corinth some two thousand years ago. But Strabo dismisses at once this idea of a difference of level, agreeing with Archimedes that the force of gravity spreads the sea equally over the earth.

When knowledge in its higher branches was confined to a few, those who possessed it were often called upon to perform many and various services for the communities to which they belonged; and we find mathematicians and astronomers, painters and sculptors, and priests called upon to perform the duties which now pertain to the profession of the architect and the engineer. And as soon as civilization had advanced so far as to admit of the accumulation of wealth and power, then kings and rulers sought to add to their glory while living by the erection of magnificent dwelling-places, and to provide for their aggrandizement after death by the construction of costly tombs and temples. Accordingly we soon find men of ability and learning devoting a great part of their time to building and architecture, and the post of architect became one of honor and profit. In one of the most ancient quarries of Egypt a royal high architect of the dynasty of the Psammetici has left his pedigree sculptured on the rock, extending back for twenty-three generations, all of whom held the same post in succession in connection with considerable sacerdotal offices.

As there were in these remote times officers whose duty it was to design and construct, so also there were those whose duty it was to maintain and repair the royal palaces and temples. In Assyria, 700 years before our era, as we know from a tablet found in the palace of Sennacherib by Mr. Smith, there was an officer whose title was the Master of works. The tablet I allude to is inscribed with a petition to the king from an officer in charge of a palace, requesting that the master of works may be sent to attend to some repairs which were much needed at the time.

Under the Roman Empire there was almost as great a division of labor in connection with building and design as now exists. The great works of that period were executed and maintained by an army of officers and workmen, who had special duties assigned to each of them.

Passing by those early attempts at design and construction which supplied the mere wants of the individual and the household, it is to the East that we must turn if we would find the earliest works which display a knowledge of

engineering. Whether the knowledge of Engineering, if we may so call it, possessed by the people of Chaldæa and Babylonia was of native growth or was borrowed from Egypt is, perhaps, a question which cannot yet be answered. Both people were agricultural, dwelling on fertile plains, intersected by great rivers, with a soil requiring water only to enable it to bring forth inexhaustible crops. Similar circumstances would create similar wants, and stimulate to action similar faculties to satisfy them. Apart from the question of priority of knowledge, we know that at a very early period, some four or five thousand years ago at least, there were men in Mesopotamia and Egypt who possessed considerable mechanical knowledge, and no little skill in hydraulic engineering. Of the men themselves we know little ; happily, works often remain when the names of those who conceived and executed them have long been forgotten.

It has been said that architecture had its origin not only in nature, but in religion ; and if we regard the earliest works which required mechanical knowledge and skill, the same may be said of engineering. The largest stones were chosen for sacred buildings, that they might be more enduring as well as more imposing, thereby calling for improvement and invention of mechanical contrivances, to assist in transporting and elevating them to the position they were to occupy ; for the same reason the hardest and most costly materials were chosen, calling for further improvement in the metal forming the tools required to work them. The working of metals was further perfected in making images of the gods, and in adorning with the more precious and ornamental sorts the interior and even external parts of their shrines.

The earliest buildings of stone to which we can assign a date with any approach to accuracy, are the pyramids of Gizeh. To their builders they were sacred buildings, even more sacred than their temples or temple palaces. They were built to preserve the royal remains, until, after a lapse of 3,000 years, which we have reason to believe was the period assigned, the spirit which had once animated the body should re-enter it. Although built 5,000 years ago, the masonry of the Pyramids could not be surpassed in these days ; all those who have seen and examined them, as I myself have done, agree in this ; moreover, the design is perfect for the purpose for which they were intended, above all to endure. This building of pyramids in Egypt continued for some ten centuries, and from 60 to 70 still remain, but none are so admirably constructed as those of Gizeh. Still, many contain enormous blocks of granite from 30 to 40 feet long, weighing more than 300 tons, and display the greatest ingenuity in the way in which the sepulchral chambers are constructed and concealed.

The genius for dealing with large masses in building did not pass away with the pyramid builders in Egypt, but their descendants continued to gain in mechanical knowledge, judging from the enormous blocks which they handled with precision. When the command of human labor was unlimited, the mere transport of such blocks as the statue of Rameses the Great, for instance, which weighed over 800 tons, need not so greatly excite our wonder ; and we know how such blocks were moved from place to place, for it is shown on the wall paintings of tombs of the period which still remain.

But as the weight of the mass to be moved is increased, it becomes no longer a question of only providing force in the shape of human bone and muscle. In moving in the last century the block which now forms the base for the statue of Peter the Great, at St. Petersburg, and which weighs 1,200 tons, force could be applied as much as was wanted, but great difficulty was experienced in supporting it, and the iron balls on which it was proposed to roll the block along were crushed, and a harder metal had to be substituted. To facilitate the transport of material, the Egyptians made solid causeways of granite from the Nile to the Pyramids ; and in the opinion of Herodotus, who saw them, the causeways were more wonderful works than the Pyramids themselves.

The Egyptians have left no record of how they accomplished a far more difficult operation than the mere transport of weight—that is, how they erected obelisks weighing more than 400 tons. Some of these obelisks must have been

lifted vertically to place them in position, as they were by Fontana in Rome in later times, when the knowledge of mechanics, we know, was far advanced.

The practice of using large blocks of stone either as monoliths or as forming parts of structures has existed from the earliest times in all parts of the world.

The Peruvians used blocks weighing from 15 to 20 tons, and fitted them with the greatest nicety in their cleverly designed fortifications.

In India large blocks were used in bridges when the repugnance of Indian builders to the use of the arch rendered them necessary, or in temples, where, as in the Temple of the Sun at Orissa, stones weighing from 20 to 30 tons form part of the pyramidal roof at a height of from 70 to 80 feet from the ground. Even as late as the last century, Indians, without the aid of machinery, were using blocks of granite above 40 feet long for the doorposts of the gateway of Seringham, and roofing blocks of the same stone for a span of 21 feet.

At Persepolis, in the striking remains of the palaces of Xerxes and Darius, more than one traveler has noted the great size of the stones, some of which are stated to be 55 feet long and 6 to 10 feet broad.

So in the Greek temples of Sicily, many of the blocks in the upper parts of the temples are from 10 to 20 tons weight.

The Romans, though they did not commonly use such large stones in their own constructions, carried off the largest obelisks from Egypt and erected them at Rome, where more are now to be found than remain in Egypt. In the temples of Baalbek, erected under Roman rule, perhaps the largest stones are to be found which have been used for building since the time of the Pharaohs. The terrace wall of one of the temples is composed of three courses of stones, none of which are less than 30 feet long ; and one stone still lies in the quarry squared and ready for transport, which is 70 feet long and 14 feet square, and weighs upwards of 1,135 tons, or nearly as much as one of the tubes of the Britannia Bridge.

I have not mentioned dolmens and menhirs, rude unhewn stones often weighing from 30 or 40 tons, which are found from Ireland to India, and from Scandinavia to the Atlas, in Africa. To transport and erect such rude masses required little mechanical knowledge or skill, and the operation has excited more wonder than it deserves. Moreover, Fergusson has gone far to show that the date assigned to many of them hitherto has been far too remote ; most, and possibly all, of those in northern and western Europe having been erected since the time of the Roman occupation. And to this day the same author shows that menhirs, single stones often weighing over 20 tons, are erected by hill tribes of India in close proximity to stone buildings of elaborate design and finished execution, erected by another race of men.

For whatever purpose these vast stones were selected—whether to enhance the value or to prolong the endurance of the buildings of which they formed a part—the tax on the ingenuity of those who moved and placed them must have tended to advance the knowledge of mechanical appliances.

The ancient Assyrians and Egyptians had possibly more knowledge of mechanical appliances than they are generally credited with. In the wall paintings and sculptures which show their mode of transporting large blocks of stone, the lever is the only mechanical power represented, and which they appear to have used in such operations ; nor ought we to expect to find any other used, for, where the supply of human labor was unlimited, the most expeditious mode of dragging a heavy weight along would be by human power ; to have applied pulleys and capstans, such as would now be employed in similar undertakings, would have been mere waste of time. In some countries, even now, where manual labor is more plentiful than mechanical appliances, large numbers of men are employed to transport heavy weights, and do the work in less time than it could be done with all our modern mechanical appliances. In other operations, such as raising obelisks, or the large stones used in their temple palaces, where human labor could not be applied to such advantage, it is quite possible that the Egyptians used mechanical aids. On one of the carved slabs which formed part of the wall panelling of the

palace of Sardanapalus, which was built about 930 years before our era, a single pulley is clearly shown, by which a man is in the act of raising a bucket—probably drawing water from a well.

It has sometimes been questioned whether the Egyptians had a knowledge of steel. It seems unreasonable to deny them this knowledge. Iron was known at the earliest times of which we have any record. It is often mentioned in the Bible, and in Homer ; it is shown in the early paintings on the walls of the tombs at Thebes, where butchers are represented as sharpening their knives on pieces of metal colored blue, which were most probably pieces of steel. Iron has been found in quantity in the ruined palaces of Assyria ; and in the inscriptions of that country fetters are spoken of as having been made of iron, which is also so mentioned in connection with other metals as to lead to the supposition that it was regarded as a base and common metal. Moreover, in the Great Pyramid a piece of iron was found in a place were it must have lain for 5,000 years. The tendency of iron to oxydize must render its preservation for any long period rare and exceptional. The quality of iron which is now made by the native races of Africa and India is that which is known as wrought iron ; in ancient times, Dr. Percy says the iron which was made was always wrought iron. It is very nearly pure iron, and a very small addition of carbon would convert it into steel. Dr. Percy says the extraction of good malleable iron directly from the ore "requires a degree of skill very far inferior to that which is implied in the manufacture of bronze." And there is no great secret in making steel ; the natives of India now make excellent steel in the most primitive way, which they have practised from time immemorial. When steel is to be made, the proportion of charcoal used with a given quantity of ore is somewhat larger, and the blast is applied more slowly than when wrought iron is the metal required. Thus, a vigorous native working the bellows of skin would make wrought iron where a lazy one would have made steel. The only apparatus required for the manufacture of the finest steel from iron ore is some clay for making a small furnace four feet high, and from one to two broad, some charcoal for fuel, and a skin with a bamboo tuyere for creating the blast.

The supply of iron in India as early as the fourth and fifth centuries seems to have been unlimited. The iron pillar of Delhi is a remarkable work for such an early period. It is a single piece of wrought iron 50 feet in length, and it weighs not less than 17 tons. How the Indians forged this large mass of iron and other heavy pieces which their distrust of the arch led them to use in the construction of roofs, we do not know. In the temples of Orissa iron was used in large masses as beams or girders in roof-work in the thirteenth century.

The influence of the discovery of iron on the progress of art and science cannot be over-estimated. India well repaid any advantage which she may have derived from the early civilized communities of the West if she were the first to supply them with iron and steel.

An interesting social problem is afforded by a comparison of the relative conditions of India and this country at the present time. India, from thirty to forty centuries ago, was skilled in the manufacture of iron and cotton goods, which manufacturers, is less than a century, have done so much for this country. It is true that in India coal is not so abundant or so universally distributed as in this country. Yet, if we look still further to the East, China had probably knowledge of the use of metals as soon as India, and moreover had a boundless store of iron and coal. Baron Richthofen, who has visited and described some of the coal-fields of China, believes that one province alone, that of Southern Shanshi, could supply the world at its present rate of consumption for several thousand years. The coal is near the surface, and iron abounds with it. Marco Polo tells us that coal was universally used as fuel in the parts of China which he visited towards the end of the fourteenth century, and from other sources we have reason to believe it was used there as fuel 2,000 years ago. But what progress has China made in the last ten centuries? A great future is undoubtedly in store for that country ; but can the race who now dwell there develop its resources, or must they await the aid of an Aryan

race? Or is anything more necessary than a change of institutions, which might come unexpectedly, as in Japan?

The art of extracting metals from the ore was practised at a very early date in this country. The existence long ago of tin mines in Cornwall, which are so often spoken of by classical writers, is well known to all. That iron was also extracted from the ore by the ancient Britons is most probable, as it was largely used for many purposes by them before the Roman conquest. The Romans worked iron extensively in the Weald of Kent, as we assume from the large heaps of slag containing Roman coins which still remain there. The Romans always availed themselves of the mineral wealth of the countries which they conquered, and their mining operations were often carried out on the largest scale, as in Spain, for instance, where as many as forty thousand miners were regularly employed in the mines at New Carthage.

Coal, which was used for ordinary purposes in England as early as the ninth century, does not appear to have been largely used for iron smelting until the eighteenth century, though a patent was granted for smelting iron with coal in the year 1611. The use of charcoal for that purpose was not given up until the beginning of this century, since which period an enormous increase in the mining and metallurgical industries has taken place; the quantity of coal raised in the United Kingdom in 1873 having amounted to 127 million tons, and the quantity of pig iron to upwards of 6½ million tons.

The early building energy of the world was chiefly spent on the erection of tombs, temples, and palaces.

While, in Egypt, as we have seen, the art of building in stone had 5,000 years ago reached the greatest perfection, so in Mesopotamia the art of building with brick, the only available material in that country, was in an equally advanced state some ten centuries later. That buildings of such a material have lasted to this day shows how well the work was done; their ruinous condition even now is owing to their having served as quarries for the last three or four thousand years, so that the name of Nebuchadnezzar, apparently one of the greatest builders of ancient times, is as common on the bricks of many modern towns in Persia as it was in old times in Babylon. The labor required to construct the brick temples and palaces of Chaldæa and Assyria must have been enormous. The mound of Koyunjik alone contained 14½ million tons, and represents the labor of 10,000 men for twelve years. The palace of Sennacherib, which stood on this mound, was probably the largest ever built by any one monarch, containing as it did more than two miles of walls, panelled with sculptured alabaster slabs, and twenty-seven portals, formed by colossal bulls and sphinxes.

The pyramidal temples of Chaldæa are not less remarkable for the labor bestowed on them, and far surpass the buildings of Assyria in the excellence of their brickwork.

The practice of building great pyramidal temples seems to have passed eastwards to India and Burmah, where it appears in buildings of a later date, in Buddhist topes and pagodas; marvels of skill in masonry, and far surpassing the old brick mounds of Chaldæa in richness of design and in workmanship. Even so late as this century a king of Burmah began to build a brick temple of the old type, the largest building, according to Fergusson, which has been attempted since the Pyramids.

The mere magnitude of many of these works is not so wonderful when we take into account the abundance of labor which those rulers could command. Countries were depopulated, and their inhabitants carried off and made to labor for the conquerors. The inscriptions of Assyria describe minutely the spoils of war and the number of captives; and in Egypt we have frequent mention made of works being executed by the labor of captive peoples. Herodotus tells us that as many as 360,000 men were employed in building one palace for Sennacherib. At the same time it must not be forgotten that the very character of the multitude would demand from some one the skill and brain to organize and direct, to design and plan the work.

It would be surprising if men who were capable of undertaking and successfully completing unproductive works of such magnitude did not also employ

their powers on works of a more useful class. Traces still remain of such works ; enough to show, when compared with the scanty records of the times which have come down to us, that the prosperity of such countries as Egypt and Mesopotamia was not wholly dependant on war and conquest, but that the reverse was more likely the case, and that the natural capabilities of those countries were greatly enlarged by the construction of useful works of such magnitude as to equal, if not in some cases surpass, those of modern times.

Egypt was probably far better irrigated in the days of the Pharaohs than it is now. To those unacquainted with the difficulties which must be met with and overcome before a successful system of irrigation can be carried out, even in countries in which the physical conditions are favorable, it may appear that nothing more is required than an adequate supply of unskilled labor. Far more than this was required : the Egyptians had some knowledge of surveying, for Eustathius says they recorded their marches on maps ; but such knowledge was probably in those days very limited, and it required no ordinary grasp of mind to see the utility of such extensive works as were carried out in Egypt and Mesopotamia, and, having seen the utility, to successfully design and execute them. To cite one in Egypt—Lake Mœris, of which the remains have been explored by M. Linant, was a reservoir made by one of the Pharaohs, and supplied by the flood waters of the Nile. It was 150 square miles in extent, and was retained by a bank or dam 60 yards wide and 10 high, which can be traced for a distance of thirteen miles. This reservoir was capable of irrigating 1,200 square miles of country. No work of this class has been undertaken on so vast a scale since, even in these days of great works.

The prosperity of Egypt was in so great a measure dependent on its great river, that we should expect that the Egyptians, a people so advanced in art and science, would at an early period have made themselves acquainted with its *régime*. We know that they carefully registered the height of the annual rise of its waters ; such registers still remain inscribed on the rocks on the banks of the Nile, with the name of the king in whose reign they were made. The people of Mesopotamia were equally observant of the *régime* of their great rivers, and took advantage in designing their canals of the different periods in the rising of the waters of the Tigris and Euphrates. A special officer was appointed in Babylon, whose duty it was to measure the rise of the river ; and he is mentioned in an inscription found in the ruins of that city, as recording the height of the water in the Temple of Bel. The Assyrians, who had a far more difficult country to deal with, owing to its rocky and uneven surface, showed even greater skill than the Babylonians in forming their can ls, tunneling through rock, and building dams of masonry across the Euphrates. While the greater number of these canals in Egypt and Mesopotamia were made for the purpose of irrigation, others seem to have been made to serve at the same time for navigation. Such was the canal which effected a junction between the Mediterranean and the Red Sea, which was a remarkable work, having regard to the requirements of the age in which it was made. Its length was about eighty miles ; its width admitted of two triremes passing one another. At least one of the navigable canals of Babylonia, attributed to Nebuchadnezzar, can compare in extent with any work of later times. I believe Sir H. Rawlinson has traced the canal to which I allude throughout the greater part of its course, from Hit on the Euphrates to the Persian Gulf, a distance of between four and five hundred miles. It is a proof of the estimation in which such works were held in Babylonia and Assyria, that, among the titles of the god Vul were those of "Lord of Canals," and "The Establisher of Irrigation Works."

The springs of knowledge which had flowed so long in Babylonia and Assyria were dried up at an early period. With the fall of Babylon and destruction of Nineveh the settled population of the fertile plains around them disappeared, and that which was desert before man led the waters over it became desert again, affording a wide field for, and one well worthy of, the labors of engineers to come.

Such was not the case with Egypt.

Long after the period of its greatest prosperity was reached, it remained the fountain head from whence knowledge flowed to Greece and Rome. The Philosophers of Greek and those who, like Archimedes, were possessed of the best mechanical knowledge of the time, repaired to Egypt to study and obtain the foundation of their knowledge from thence.

Much as Greece and Rome were indebted to Egypt, it will probably be found, as the inscribed tablets met with in the mounds of Assyria and Chaldæa are deciphered, that the latter civilizations owe, if not more, at least as much, to those countries as to Egypt. This is the opinion of Mr. Smith, who, in his work describing his recent interesting discoveries in the East, says that the classical nations "borrowed far more from the valley of the Euphrates than that of the Nile."

In the science of astronomy, which in these days is making such marvellous discoveries, Chaldæa was undoubtedly preeminent. Among the many relics of these ancient peoples which Mr. Smith has recently brought to this country is a portion of a metal astrolabe from the palace of Sennacherib, and a tablet on which is recorded the division of the heavens according to the four seasons, and the rule for regulating the intercalary month of the year. Not only did the Chaldæans map out the heavens and arrange the stars, but they traced the motion of the planets, and observed the appearance of comets; they fixed the signs of the zodiac, and they studied the sun and moon and the periods of eclipses.

But to return to that branch of knowledge to which I wish more particularly to draw your attention, as it grew and spread from east to west, from Asia over Europe. Of all nations of Europe the Greeks were most intimately connected with the civilization of the East. A maritime people by the nature of the land they lived in, colonization followed as a matter of course on the tracks of their trading vessels; and thus, more than any other people, they helped to spread Eastern knowledge along the shores of the Mediterranean, and throughout the shores of Europe.

The early constructive works of Greece, till about the seventh century B. C., form a strong contrast to those of its more prosperous days. Commonly called Pelasgian, they are more remarkable as engineering works than admirable as those which followed them were for architectural beauty. Walls of huge unshapely stones—admirably fitted together, however—tunnels and bridges characterize this period. In Greece, during the few and glorious centuries which followed, the one aim in all construction was to please the eye, to gratify the sense of beauty; and in no age was that aim more thoroughly and satisfactorily attained.

In these days, when sanitary questions attract each year more attention, we may call to mind that twenty-three centuries ago the city of Agrigentum possessed a system of sewers, which, on account of their large size, were thought worthy of mention by Diodorus. This is not, however, the first record of towns being drained; the well known Cloaca Maxima, which formed part of the drainage system of Rome, was built some two centuries earlier, and great vaulted drains passed beneath the palace mounds of unburnt brick at Nimrod and Babylon; and possibly we owe the preservation of many of the interesting remains found in the brick mounds of Chaldæa to the very elaborate system of pipe drainage discovered in them, and described by Loftus.

Whilst Pelasgian art was being superseded in Greece, the city of Rome was founded in the eighth century before our era; and Etruscan art in Italy, like the Pelasgian art in Greece, was slowly merged in that of an Aryan race. The Etruscans, like the Pelasgians and the old Egyptians, were Turanians, and remarkable for their purely constructive or engineering works. Their city walls far surpass those of any other ancient race, and their drainage works and tunnels are most remarkable.

The only age which can compare with the present one in the rapid extension of utilitarian works over the face of the civilized world, is that during which the Romans, an Aryan race, as we are, were in power. As Fergusson has said, the mission of the Aryan races appears to be to pervade the world with useful and industrial arts. That the Romans adorn-

ed their bridges, their aqueducts, and their roads; that with a sound knowledge of construction they frequently made it subservient to decoration, was partly owing to the mixture of Etruscan or Turanian blood in their veins, and partly to their great wealth, which made them disregard cost in their construction, and to their love of display.

It would be impossible for me to do justice to even a small part of the engineering works which have survived fourteen centuries of strife, and remain to this day as monuments of the skill, the energy, and ability of the great Roman people. Fortunately, their works are more accessible than those of which I have spoken hitherto, and many of you are probably already familiar with them.

Conquerors of the greater part of the civilized world, the admirable organization of the Romans enabled them to make good use of the unbounded resources which were at their disposal. Yet, while the capital was enriched, the development of the resources of the most distant provinces of the empire was never neglected.

War, with all its attendant evils, has often indirectly benefited mankind. In the long sieges which took place during the old wars of Greece and Rome, the inventive power of man was taxed to the utmost to provide machines for attack and defence. The ablest mathematicians and philosophers were pressed into the service, and helped to turn the scale in favor of their employers. The world has to regret the loss of more than one, who, like Archimedes, fell slain by the soldiery while applying the best scientific knowledge of the day to devising means of defence during the siege. In these days, too, science owes much to the labors of engineers and able men, whose time is spent in making and improving guns, the materials composing them, and armor plates to resist them, or in studying the motion of ships of war in a seaway.

The necessity for roads and bridges for military purposes has led to their being made where the necessary stimulus from other causes was wanting; and so means of communication, and the interchange of commodities, so essential to the prosperity of any community, have thus been provided. Such was the case under the Roman Empire. So, too, in later times the ambition of Napoleon covered France and the countries subject to her with an admirable system of military roads. At the same time, we must do Napoleon the justice of saying that his genius and foresight gave a great impetus to the construction of all works favorable to commercial progress. So, again, in this country it was the rebellion of 1745, and the want felt of roads for military purposes, which first led to the construction of a system of roads in it unequaled since the time of the Roman occupation. And lastly, in India, in Germany, and in Russia, more than one example could be pointed out where industry will benefit by railways which have originated in military precautions rather than in commercial requirements.

But to return to Rome. Roads followed the tracks of her legions into the most distant provinces of the empire. Three hundred and seventy-two great roads are enumerated, together more than 48,000 miles in length, according to the itinerary of Antoninus.

The water supply of Rome during the first century of our era would suffice for a population of seven millions, supplied at the rate at which the present population of London is supplied. This water was conveyed to Rome by nine aqueducts; and in later years the supply was increased by the construction of five more aqueducts. Three of the old aqueducts have sufficed to supply the wants of the city in modern times. These aqueducts of Rome are to be numbered among her grandest engineering works. Time will not admit of my saying anything about her harbor works and bridges, her basilicas and baths, and numerous other works in Europe, in Asia, and in Africa. Not only were these works executed in a substantial and perfect manner, but they were maintained by an efficient staff of men divided into bodies, each having their special duties to perform. The highest officers of state superintended the construction of works, were proud to have their names associated with them, and constructed extensive works at their own expense.

Progress in Europe stopped with the fall of the Roman Empire. In the

fourth and succeeding centuries the barbarian hordes of Western Asia, people who felt no want of roads and bridges, swept over Europe to plunder and destroy.

With the seventh century began the rise of the Mohammedan power, and a partial return to conditions apparently more favorable to the progress of industrial art, when widespread lands were again united under the sway of powerful rulers. Science owes much to Arab scholars, who kept and handed on to us the knowledge acquired so slowly in ancient times, and much of which would have been lost but for them. Still, few useful works remain to mark the supremacy of the Mohammedan power at all comparable to those of the age which preceded its rise.

A great building age began in Europe in the tenth century, and lasted through the thirteenth. It was during this period that these great ecclesiatical buildings were erected, which are not more remarkable for artistic excellence than for boldness in design.

While the building of cathedrals progressed on all sides in Europe, works of utilitarian character, which concern the engineer, did not receive such encouragement, excepting perhaps in Italy.

From the twelfth to the thirteenth centuries, with the revival of the arts and sciences in the Italian republics, many important works were undertaken for the improvement of the rivers and harbors of Italy. In 1481 canal locks were first used ; and some of the earliest of which we have record were erected by Leonardo da Vinci, who would be remembered as a skillful engineer had he not left other greater and more attractive works to claim the homage of posterity.

The great use that has since been made of this simple means of transferring floating vessels from one water level to another, in connection not only with inland navigation, but in all the great ports and harbors of the world, renders it all the more deserving of remark.

In India, under the Moguls, irrigation works, for which they had a natural aptitude, were carried on during these centuries with vigor, and more than one emperor is noted for the numerous great works of this nature which he carried out. If the native records can be trusted, the number of hydraulic works undertaken by some rulers is surprising. Tradition relates that one king who reigned in Orissa in the twelfth century made one million tanks or reservoirs, besides building sixty temples, and erecting numerous other works.

In India, the frequent overflow of the great rivers, and the periodical droughts, which rendered irrigation necessary, led to extensive protective works being undertaken at an early period ; but as these works have been maintained by successive rulers, Mogul and Mohammedan, until recent times, and have not been left for our inspection, deserted and useless for 3,000 years or more, as is often the case in Egypt and Mesopotamia, there is more difficulty in ascertaining the date of such works in India.

Works of irrigation were among the earliest attempts at engineering undertaken by the least civilized inhabitants in all parts of the world. Even in Australia, where savages are found as low as any in the scale of civilization, traces of irrigation works have been found ; these works, however, must be taken to show that the natives were once somewhat more civilized than we now find them. In Feejce, our new possession, the natives occasionally irrigate their land, and have executed a work of a higher class, a canal some two miles long and sixty feet wide, to shorten the distance passed over by their conoes. The natives of New Caledonia irrigate their fields with great skill. In Peru, the Incas excelled in irrigation as in other great and useful works, and constructed most admirable underground conduits of masonry for the purpose of increasing the fertility of the land.

It is frequently easier to lead water where it is wanted than to check its irruption into places where its presence is an evil, often a disaster. For centuries the existence of a large part of Holland has been dependent on the skill of man. How soon he began in that country to contest with the sea the possession of the land we do not know, but early in the twelfth century dykes were constructed to keep back the ocean. As the prosperity of the country increased with the great extension of its

commerce, and land became more valuable and necessary for an increasing population, very extensive works were undertaken. Land was reclaimed from the sea, canals were cut, and machines were designed for lifting water. To the practical knowledge acquired by the Dutch, whose method of carrying out hydraulic works is original and of native growth, much of the knowledge of the present day in embanking, and draining, and canal making is due. The North Holland Canal was the largest navigable canal in existence until the Suez Canal was completed ; and the Dutch have just now nearly finished making a sea canal from Amsterdam to the North Sea, which, though not equal to the Suez Canal in length, will be as great in width and depth, and involves perhaps larger and more important works of art. This country was for many years beholden to the Dutch for help in carrying out hydraulic works. In the seventeenth century much fen land in the eastern counties was drained by Dutch labor, directed by Dutch engineers, among whom Sir Cornelius Vermuyden, an old campaigner of the Thirty Years' War and a colonel of horse under Cromwell, is the most noted.

While the Dutch were acquiring practical knowledge in dealing with water, and we in Britain among others were benefiting by their experience, the disastrous results which ensued from the inundations caused by the Italian rivers of the Alps gave a new importance to the science of hydraulics. Some of the greatest philosophers of the seventeenth century—among them Torricelli, a pupil of Galileo,—were called upon to advise and to superintend engineering works; nor did they confine themselves to the construction of preventive works, but thoroughly investigated the condition pertaining to fluids at rest or in motion, and gave to the world a valuable series of works on hydraulics and hydraulic engineering, which form the basis of our knowledge of these subjects at the present day.

Some of the best scientific works (prior to the nineteenth century) on engineering subjects we owe to Italian and French writers. The writings of Belidor, an officer of artillery in France in the seventeenth century, who did not, however, confine himself to military subjects, drew attention to engineering questions. Not long after their appearance, the Ponts et Chausees were established, which has maintained ever since a body of able men specially educated for, and devoted to, the prosecution of industrial works.

The impulse given to road-making in the early part of the last century soon extended to canals and means for facilitating locomotion and transport generally. Tramways were used in connection with mines at least as early as the middle of the seventeenth century, but the rails were, in those days, of wood. The first iron rails are said to have been laid in this country as early as 1738 ; after which time their use was gradually extended, until it became general in mining districts.

By the beginning of this century the great ports of England were connected by a system of canals ; and new harbor works became necessary, and were provided to accommodate the increase of commerce and trade, which improved means of internal transport had rendered possible. It was in the construction of these works that our own Brindley and Smeaton, Telford and Rennie, and other engineers of their time, did so much.

But it was not untill the steam-engine, improved and almost created by the illustrious Watt, became such a potent instrument, that engineering works to the extent they have since been carried out became possible or necessary. It gave mankind no new faculty, but it at once set his other faculties on an eminence, from which the extent of his future operations became almost unlimited.

Water-mills, wind-mills, and horse-machines were in most cases superseded. Deep mines, before only accessible by adits and water levels, could at once be reached with ease and economy. Lakes and fens which, but for the steam-engine, would have been left untouched, were drained and cultivated.

The slow and laborious toil of hands and fingers, bone and sinew, was turned to other employments, where, aided by ingenious mechanical contrivances, the produce of one pair of hands was multiplied a thousand-fold, and their cunning

extended until results marvelous, if you consider them, were attained. Since the time of Watt the steam-engine has exerted a power, made conquests, and increased and multiplied the material interests of this globe to an extent which it is scarcely possible to realize.

But while Watt has gained a world-wide, well-earned fame, the names of those men who have provided the machines to utilize the energies of the steam-engines are too often forgotten. Of their inventions the majority of mankind know little. They worked silently at home, in the mill, or in the factory, observed by few. Indeed, in most cases these silent workers had no wish to expose their work to public gaze. Were it not so, the factory and the mill are not places where people go to take the air. How long in the silent night the inventors of these machines sat and pondered ; how often they had to cast aside some long-sought mechanical movement and seek another and a better arrangement of parts, none but themselves could ever know. They were unseen workers, who succeeded by rare genius, long patience, and indomitable perseverance.

More ingenuity and creative mechanical genius is perhaps displayed in machines used for the manufacture of textile fabrics than by those used in any other industry. It was not until late in historical times that the manufacture of such fabrics became established on a large scale in Europe. Although in China man was clothed in silk long ago, and although Confucius, in a work written 2,300 years ago, orders with the greatest minuteness the rules to be observed in the production and manufacture of silk, yet it was worth nearly its weight in gold in Europe in the time of Aurelian, whose empress had to forego the luxury of a silk gown on account of its cost? Through Constantinople and Italy the manufacture passed slowly westwards, and was not established in France until the sixteenth century, and arrived at a still later period in this country. It is related that James V. had to borrow a pair of silk hose from the Earl of Mar, in order that he might not, as he expressed it, appear as a scrub before strangers.

So cotton, of which the manufacture in India dates from before historical times, had scarcely by the Christian era reached Persia and Egypt. Spain in the tenth and Italy in the fourteenth century manufactured it, but Manchester, which is now the great metropolis of the trade, not until the latter half of the seventeenth century.

Linen was worn by the old Egyptians, and some of their linen mummy cloths surpass in fineness any linen fabrics made in later days. The Babylonians wore linen also and wool, and obtained a wide-spread fame for skill in workmanship and beauty in design.

In this country wool once formed the staple for clothing. Silk was the first rival, but its costliness placed it beyond the reach of the many. To introduce a new material or improved machine into this or other countries a century or more ago was no light undertaking. Inventors and would-be benefactors alike, ran the risk of loss of live. Loud was the outcry made in the early part of the eighteenth century against the introduction of Indian cottons and Dutch calicoes.

Until 1738, in which year the improvements in spinning machinery were begun, each thread of worsted or cotton wool had been spun between the fingers in this and all other countries. Wyatt, in 1738, invented spinning by rollers instead of fingers, and his invention was further improved by Arkwright. In 1770 Hargreaves patented the spinning jenny, and Crompton the mule in 1775, a machine which combined the advantages of the frames of both Hargreaves and Arkwright. In less than a century after the first invention by Wyatt, double mules were working in Manchester with over 2,000 spindles. Improvements in machines for weaving were begun at an earlier date. In 1579 a ribbon loom is said to have been invented at Dantzic, by which from four to six pieces could be woven at one time, but the machine was destroyed and the inventor lost his life. In 1800 Jacquard's most ingenious invention was brought into use, which, by a simple mechanical operation, determines the movements of the threads which form the pattern in weaving. But the greatest discovery in the art of weaving was wrought by Cartwright's discovery of the power loom, which led eventually to the sub-

stitution of steam for manual labor, and enabled a boy with a steam loom to do fifteen times the work of a man with a hand loom.

Steamboats, the electric telegraph, and railways, are more within the cognizance of the world at large, and the progress that has been made in them in little more than one generation is better known and appreciated.

It is not more than forty years since one of our scientific men, and an able one too, declared at a meeting of this Association that no steamboat would ever cross the Atlantic ; founding his statement on the impracticability, in his view, of a steamboat carrying sufficient coal, profitably, I presume, for the voyage. Yet, soon after this statement was made, the *Sirius* steamed from Bristol to New York in seventeen days, and was soon followed by the *Great Western*, which made the homeward passage in thirteen-and-a-half days ; and with these voyages the era of steamboats began. Like most important inventions, that of the steamboat was a long time in assuming a form capable of being profitably utilized ; and even when it had assumed such a form, the objections of commercial and scientific men had still to be overcome.

The increase in the number of steamboats since the time when the *Sirius* first crossed the Atlantic has been very great. Whereas in 1814 the United Kingdom only possessed two steam vessels, of together 456 tons burden, in 1872 there were on the register of the United Kingdom 3,662 steam vessels, of which the registered tonnage amounted to over a million and a half of tons, or to nearly half the whole steam tonnage of the world, which did not at that time greatly exceed three million tons.

As the number of steamboats has largely increased, so also gradually has their size increased until it culminated in the hands of Brunel in the *Great Eastern.*

A triumph of engineering skill in shipbuilding, the *Great Eastern* has not been commercially so successful. In this, as in many other engineering problems, the question is not how large a thing can be made, but how large, having regard to other circumstances, it is proper at the time to make it.

If, as regards the dimensions of steamboats, we have at present somewhat overstepped the limits in the *Great Eastern*, much still remains to be done in perfecting the form of vessels, whether propelled by steam or driven by the force of the wind. A distinguished member of this Association, Mr. Froude, has now for some years devoted himself to investigations carried on with a view to ascertain the form of vessel which will offer the least resistance to the water through which it must pass. So many of us in these days are called upon to make journeys by sea as well as by land, that we can well appreciate the value of Mr. Froude's labors, so far as they tend to curtail the time which we must spend on our ocean journeys ; and we should all feel grateful to him if from another branch of his investigations, which relates to the rolling of ships, it should result that the movement in passenger vessels could be reduced.

As improvements in the form of the hull are effected, less power—that is, less fuel—will be required to propel the vessel through the water for a given distance. Great as have been the improvements effected in marine engines to this end, much still remains to be done. Wolf's compound engine, so long overlooked, is, with some improvements, being at last applied. Whereas the consumption of fuel in such vessels as the *Himalaya* used to be from 5 to 6 lbs. of fuel per effective horse-power, it has been reduced, by working steam more expansively in vessels of a later date, to 2 lbs. Yet, comparing this with the total amount of energy of 2 lbs. of coal, it will be found that not a tenth part of the power is obtained which that amount of coal would theoretically call into action.

There is no more remarkable instance of the rapid utilization of what was in the first instance regarded by most men as a mere scientific idea, than the adoption and extension of the electric telegraph.

Those who read Odier's letter written in 1773, in which he made known his idea of a telegraph which would enable the inhabitants of Europe to converse with the Emperor of Mogul, little thought that in less than a century a

conversation between persons at points so far distant would be possible. Still less did those who saw in the following year messages sent from one room to another by Lesage in the presence of Friedrich of Prussia, realize that they had before them the germ of one of the most extraordinary inventions among the many that will render this century famous.

I should weary you were I to follow the slow steps by which the electric telegraph of to-day was brought to its present state of efficiency. In the present century few years have passed without new workers appearing in the field; some whose object was to utilize the new-found power for the benefit of mankind, others—and their work was not the least important in the end—whose object was to investigate magnetism and electrical phenomena as presenting scientific problems still unsolved. Galvani, Volta, Oersted, Arago, Sturgeon, and Faraday, by their labors, helped to made known the elements which rendered it possible to construct the electric telegraph. With the battery, the electric coil, and the electro-magnet, the elements were complete, and it only remained for Sir Charles Wheatstone and others to combine them in a useful and practically valuable form. The inventions of Alexander, Steinheil, and those of similar nature to that of Sir Charles Wheatstone, were made known at a later date in the same year, which will ever be memorable in the annals of telegraphy.

The first useful telegraph was constructed upon the Blackwall Railway in 1838, Messrs. Wheatstone's and Cooke's instruments being employed. From that time to this the progress of the electric telegraph has been so rapid, that at the present time, including land lines and submarine cables, there are in use in different parts of the world not less than 400,000 miles of telegraph.

Among the numerous inventions of late years, the outomatic telegraph of Mr. Alexander Bain, of Dr. Werner Siemens, and of Sir Charles Wheatstone, are especially worthy of notice. Mr. Bain's machine is cheifly used in the United States, that of Dr. Werner Siemens in Germany. In this country the machine invented by Sir Charles Wheatstone, to whom telegraphy owes so much, is chiefly employed. By his machine, after the message has been punched out in a paper ribbon by one machine on a system analogous to the dot and dash of Morse, the sequence of the currents requisite to transmit the message along the wire is automatically determined in a second machine by this perforated ribbon. This second operation is analogous to that by which in Jacquard's loom the motions of the threads requisite to produce the pattern is determined by perforated cards. By Wheatstone's machine errors inseparable from manual labor are avoided; and what is of even more importance in a commercial point of view, the time during which the wire is occupied in the transmission of a message is considerably diminished.

By the application of these automatic systems to telegraphy, the speed of transmission has been wonderfully accelerated, being equal to 200 words a minute, that is, faster than a shorthand writer can transcribe; and, in fact, words can now be passed along the wires of land lines with a velocity greater than can be dealt with by the human agency at either end.

Owing partly to the retarding effects of induction and other causes, the speed of transmission by long submarine cables is much smaller. With the cable of 1858 only 2½ words per minute were got through. The average with the Atlantic cable, Dr. C. W. Siemens informs me, is now seventeen words, but twenty-four words per minute can be read.

One of the most striking phenomena in telegraphy is that known as the duplex system, which enables messages to be sent from each end of the same wire at the same time. This simultaneous transmission from both ends of a wire was proposed in the early days of telegraphy, but, owing to imperfect insulation, was not then found to be practicable; but since then telegraphic wires have been better insulated, and the system is now becoming of great utility, as it nearly doubles the capacity for work of every wire.

Of railways the progress has been enormous, but I do not know that in a scientific point of view a railway is so marvelous in its character as the electric telegraph. The results, however,

of the construction and use of railways are more extensive and widespread, and their utility and convenience brought home to a larger portion of mankind. It has come to pass, therefore, that the name of George Stephenson has been placed second only to that of James Watt; and as men are and will be estimated by the advantages which their labors confer on mankind, he will remain in that niche, unless indeed some greater luminary should arise to outshine him. The merit of George Stephenson consisted, among other things, in this, that he saw more clearly than any other engineer of his time the sort of thing that the world wanted, and that he persevered in despite of learned objectors with the firm conviction that he was right and they were wrong, and that there was within himself the power to demonstrate the accuracy of his convictions.

We who live in these days of roads and railways, and can move with a fair degree of comfort, speed, and safety, almost where we will, can scarcely realize the state of England two centuries ago, when the years of opposition which preceded the era of coaches began; when, as in 1662, there were but six stages in all England, and John Crossdell, of the Charterhouse, thought there were six too many; when Sir Henry Herbert, a member of the House of Commons, could say, "If a man were to propose to carry us regularly to Edinburgh in coaches in seven days, and bring us back in seven more, should we not vote him to Bedlam?"

In spite of short-sighted opposition, coaches made their way; but it was not till a century later, in 1784,—and then I believe it was in this city of Bristol—that coaches were first established for the conveyance of mails. Those here who have experienced, as I have, what the discomforts were of long journeys inside the old coaches, will agree with me that they were very great; and I believe, if returns could be obtained of the accidents which happened to coaches, it would be found that many more people were injured and killed in proportion to the number that traveled by that mode than by the railways of to-day.

No sooner had our ancestors settled down with what comfort was possible in their coaches, well satisfied that twelve miles an hour was the maximum speed to be obtained or that was desirable, than they were told that steam conveyance on iron railways would supersede their "present pitiful" methods of conveyance. Such was the opinion of Thomas Gray, the first promoter of railways, who published his work on a general iron railway in 1819. Gray was looked on as little better than a madman.

Railways add enormously to the national wealth. More than twenty-five years ago it was proved to the satisfaction of a committee of the House of Commons, from facts and figures which I then adduced, and the Lancashire and Yorkshire Railway, of which I was the engineer, and which then formed the principal railway connection between the populous towns of Lancashire and Yorkshire, effected a saving to the public using the railway of more than the whole amount of the dividend which was received by the proprietors. These calculations were based solely on the amount of traffic carried by the railway, and on the difference between the railway rate of charge and the charges by the modes of conveyance anterior to railways. No credit whatever was taken for the saving of time, though in England preeminently time is money.

Considering that railway charges on many items have been considerably reduced since that day, it may be safely assumed that the railways in the British Islands now produce, or rather save to the nation, a much larger sum annually than the gross amount of all the dividends payable to the proprietors, without at all taking into account the benefit arising from the saving in time. The benefits under that head defy calculation, and cannot with any accuracy be put into money; but it would not be at all over-estimating this question to say that in time and money the nation gains at least what is equivalent to 10 per cent. on all the capital expended on railways. I do not urge this on the part of railway proprietors, for they did not embark in these undertakings with a view to the national gain, but for the expected profit to themselves. Yet it is as well it should be noted, for railway proprietors appear sometimes by some

people to be regarded in the light of public enemies.

It follows from these facts that whenever a railway can be made at a cost to yield the ordinary interest of money, it is in the national interest that it should be made. Further, that though its cost might be such as to leave a smaller dividend than that to its proprietors, the loss of wealth to so small a section of the community will be more than supplemented by the national gain, and therefore there may be cases where a Government may wisely contribute in some form to undertakings which, without such aid, would fail to obtain the necessary support.

Mr. Bramwell, when presiding over the Mechanical Section at Brighton, drew attention to the waste of fuel.

Dr. Siemens, in an able lecture he delivered by request of the Association to the operative classes at the meeting at Bradford, pointed out the waste of fuel in special branches of the iron trade, to which he has devoted so much attention.

He showed on that occasion that, in the ordinary re-heating furnace, the coal consumed did not produce the twentieth part of its theoretical effect, and in melting steel in pots in the ordinary way not more than one-seventieth part; in melting one ton of steel in pots about 2½ tons of coke being consumed. Dr. Siemens further stated that, in his regenerative gas furnace, one ton of steel was melted with 12 cwt. of small coal.

Mr. Lowthian Bell, who combines chemical knowledge with the practical experience of an ironmaster, in his Presidential address to the members of the Iron and Steel Institute in 1873, stated that, with the perfect mode of withdrawing and utilizing the gases and the improvement in the furnaces adopted in the Cleveland district, the present make of pig-iron in Cleveland is produced with 3½ million tons of coal less than would have been needed fifteen years ago; this being equivalent to a saving of 45 per cent. of the quantity formerly used. He shows by figures, with which he has favored me, that the calorific power of the waste gases from the furnaces is sufficient for raising all the steam and heating all the air the furnaces require.

It has already been stated that by working steam more expansively, either in double or single engines, the consumption of fuel in improved modern engines compared with the older forms may be reduced to one-third.

All these reductions still fall far short of the theoretical effect of fuel which may be never reached. Mr. Lowthian Bell's figures go to show that in the interior of the blast furnace, as improved in Cleveland, there is not much more to be done in reducing the consumption of fuel; but much has already been done, and could the reductions now attainable, and all the information already acquired be universally applied, the saving in fuel would be enormous.

If I have pointed out that we do not avail ourselves of more than a fractional part of the useful effects of fuel, it is not that I expect we shall all at once mend our ways in this respect. Many cases of waste arise from the existence of old and obsolete machines, of bad forms of furnaces, of wasteful grates, existing in most dwelling-houses; and these are not to be remedied at once, for not everyone can afford, however desirable it might be, to cast away the old and adopt the new.

In looking uneasily to the future supply and cost of fuel, it is, however, something to know what may be done even with the application of our present knowledge; and could we apply it universally to-day, all that is necessary for trade and comfort could probably be as well provided for by one-half the present consumption of fuel; and it behoves those who are beginning to build new mills, new furnaces, new steamboats, or new houses, to act as though the price of coal which obtained two years ago had been the normal and not the abnormal price.

"Whence and whither," is an aphorism which leads us away from present and plainer objects to those which are more distant and obscure; whether we look backwards or forwards, our vision is speedily arrested by an impenetrable veil.

On the subjects I have chosen you will probably think I have traveled backwards far enough. I have dealt to some extent with the present.

The retrospect, however, may by use-

ful to show what great works in former ages.

Some things have been better done than in those earlier times, but not all.

In what we choose to call the ideal we do not surpass the ancients. Poets and painters and sculptors were as great in former times as now; so, probably, were the mathematicians.

In what depends on the accumulation of experience, we ought to excel our forerunners. Engineering depends largely on experience; nevertheless, in future times, whenever difficulties shall arise or works have to be acomplished for which there is no precedent, he who has to perform the duty may step forth from any of the walks of life, as engineers have not unfrequently hitherto done.

The marvelous progress of the last two generations should make everyone cautious of predicting the future. Of engineering works, however, it may be said that their practicability or impracticability is often determined by other elements than the inherent difficulty in the works themselves. Greater works than any yet achieved remain to be accomplished—not perhaps yet awhile. Society may not yet require them; the world could not at present afford to pay for them.

The progress of engineering works, if we consider it, and the expenditure upon them, has already in our time been prodigious. One hundred and sixty thousand miles of railway alone, put into figures at 20,000*l.* a mile, amounts to 3,200 million pounds sterling; add 400,000 miles of telegraph at 100*l.* a mile, and 100 millions more for sea canals, docks, harbors, water and sanitary works constructed in the same period, and we get the enormous sum of 3,340 millions sterling expended in one generation and a half on what may undoubtedly be called useful works.

The wealth of nations may be impaired by expenditure on luxuries and war; it cannot be diminished by expenditure on works like these.

As to the future, we know we cannot create a force; we can, and no doubt shall, greatly improve the application of those with which we are acquainted. What are called inventions can do no more than this, yet how much every day is being done by new machines and instruments.

The telescope extended our vision to distant worlds. The spectroscope has far outstripped that instrument, by extending our powers of analysis to regions as remote.

Postal deliveries were and are great and able organizations, but what are they to the telegraph?

Need we try to extend our vision into futurity farther? Our present knowledge, compared to what is unknown even in physics, is infinitesimal. We may never discover a new force—yet, who can tell?

REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers.—The last issue of the "Transactions" contains papers and discussions of the Annual Convention not before published.

On Pumping Engines by W. M. Roberts, D. M. Greene and J. H. Harlow;—On Compound Engines by J. W. Hill;—On Rails by A. L. Holley, W. Metcalf and W. W. Evans; —On Railway Signals, C. H. Fisher, J. D. Steele, W. P. Shinn and C. Paine;—On Rapid Transit in large cities;—by R. H. Buel, C. H. Fisher, J. D. Steele and W. H. Searles.

The present issue contains also a detailed account of the failure of the Brainerd Bridge, with suggestions as to the cause.

IRON AND STEEL NOTES.

Use of Rail Ends in Blast Furnaces.—Heyrowsky says that there are different methods for using rail ends in the Bessemer process, and that it is acknowledged that 20 to 25 per cent. can be introduced into the Bessemer retort without any objection. Another use has lately been tried with success at the Zeltweg blast furnace, and as Zeltweg possesses a large balance of rail ends this work is very important. The production of the furnace heretofore has been 4,600 cwt. of grey Bessemer pig per week; now it is 5,400 cwt. This difference of 800 cwt. corresponds exactly to the quantity of rail ends used. In like manner, instead of rail ends, grey and even white cast iron could be used without diminishing the economical results.—*Mining Journal.*

Remarkably Large Yield of Pig Iron by a Charcoal Furnace.—From a recent number of the Marquette Mining Journal we take the following statement of the work done by Bay furnace, No. 2, at Onota, Michigan, during the month of August last: Number of gross tons of pig iron made, 1,109¾; average make per day, 35.78 tons; highest daily yield, Aug. 20th, 41½ tons; lowest daily yield, Aug. 7th, 31 tons; yield on the first day of the month, 35 tons; yield on the last day of the month, 36 tons; average yield of the ore, 60.31

per cent.; number of bushels of charcoal used to the ton of iron 101.98; total number of charges in the month, 3,770; total number of pounds of ore charged, 4,120,550; total number of bushels of charcoal used, 113,100. The iron was of the following grades: No. 1, 915¼ tons; No. 2, 185¼ tons, and No. 3, 8¾ tons: total, 1,109¼ gross tons. During the seven days beginning on the 19th and ending on the 25th, 276½ gross tons were made, which is believed to be the largest week's make yet attained by a charcoal furnace. This furnace is 45 feet high, and 9½ feet across the bosh. H. S. Pickands is Superintendent.—*Bulletin.*

Revolution in the Production and Treatment of Iron and Steel.—One of the most important patents which have ever been granted for the production of iron and steel will be found, says *Capital and Labor*, in that recently granted to Messrs. Samuel R. Smyth and Joseph Simpson, of No. 58 Fountain-street, Manchester. This patent commences with an exhaust vacuum furnace, and its operations extend to the manufacture of the finest productions in iron and steel. It is, however, so complete in its character that portions can be applied to existing blast furnaces, Bessemer convertors, or Siemens' furnaces. Masses of metal of twenty-five tons in weight can be treated at one time in the patentees' patent metal receiver, which forms an important feature in the invention. In it the molten metal can be purified and refined into any quality of iron, or it may be converted into steel. The cost of producing iron or steel of any quality by means of this patent process is enormously reduced. By the use of the patentees' comparatively inexpensive exhaust vacuum furnace the metal can be smelted without the necessity of providing blast engines, and it is never allowed to cool from that point until it has been manipulated into a finished production. In the manufacture of steel the purifying process (which only occupies a few minutes) enables steel to be produced from Cleveland, Lincolnshire, or Northamptonshire iron, or even from cinder pig, because the objectionable metalloids in the iron are either removed or rendered quite innocuous by the use of the compounds applied by the patentees in their apparatus. The iron being thus purified and refined, steel can be produced therefrom, by their process, without the use of spiegeleisen, In applying the process to Bessemer convertors or to Siemens' furnaces it may, however, be necessary to use a small amount of spiegel. In working this invention throughout it is a notable feature that solid fuel only comes once into contact with the metal. The gases from the coal are stored in a gasholder, and, along with those evolved in the vacuum smelting furnace, they are used in heating the furnaces for the further manipulation of the metal. By this means all the combustible properties in the coal are made use of, and after the gases have supplied all the carbonic oxyde necessary for completing the further stages of production. It is, lastly, used for raising the steam required in the boilers on the premises. By this means the consumption of fuel is reduced to the lowest minimum possible. By the patentees' method of treatment any weight of charge of metal can be purified and refined at once, and converted into steel if desired. The metal can also be held in its molten state in the patent metal receiver for any length of time which may be desired, without any waste of material, inasmuch as the metal can be oxydized or de-oxydized, carbonized or de-carbonized in the metal receiver any number of times at the will of the manipulator. By this process also a plate, casting, or forging of any weight can be produced without any laminations, because in the metal receiver every atom of the metal will be of perfect evenness of quality, ductility, and density. This important invention is the result of years of careful examination and study, and the practical results which have been obtained by the application of the invention to adequate quantities of metal are such as to justify even more sanguine statements that are made herein.

Mechanical Aids to Puddling.—We note that ironmasters, who are not experimenting with rotary furnaces, are still casting about for a means of puddling their iron with as little manual labor as is practicable. The difficulties arising out of the want of enough puddlers sufficiently skilled to do their work properly, is driving the finished iron trade in most parts of the kingdom to seek mechanical aid, which they would otherwise not be anxious about. When men have once set up a plan, there is a pardonable reluctance to interfere with it, so long as it can be made to serve the purpose for which it was originally designed. Single-hand puddling furnaces were well enough when the demand for iron was less than now, or when men were more abundant in proportion to the demand; but now that the aggregate of the requirements of the iron-consuming world is vast, and puddlers are scarce, it becomes a necessity that a method of making finished iron in its early stages should be adopted by which a larger quantity than heretofore may be got out in the same time. Moreover, such is now the competition in the manufacture of iron, both at home and abroad, that rigid economy must be enforced. Where, therefore, ironmasters are not prepared to adopt revolving machinery, they are seeking out and adopting the best form of double furnace, worked in part by machinery, and possessing a heating chamber for warming the pig iron before it is thrown into the puddling furnace. One such furnace is known in Yorkshire as the "Joe Pickles" furnace—Mr. Pickles having been a millwright in the service of the Kirkstall Iron Company, by whom the furnace is made. There is nothing remarkably striking about it, but practical men are giving increased attention to it, and it is now being adopted outside Yorkshire. The furnace has an opening on each side, so that two men can be simultaneously employed upon it. In a double furnace of this description the back wall, with all its cost of fettling and frequent repairing, is dispensed with, and by reducing the area to be heated there is economy in the

consumption of fuel. The pigs are heated in a chamber on each side of the flue. The puddling machine consists of a frame fastened to the outer plates of the furnace. Upon this frame is fixed a small steam engine, which is arranged so as to move a beam up and down. From each end of this beam a crank is worked, having at its proximity a forked swivel, and in this the rabble or tool is fixed. The vertical movement of the beam gives a horizontal motion to one end of the crank to which the tool is attached, so that instead of the puddler or underhand having to work the iron while it is in a fluid state the machine does it, and all the workmen have to do is to change the rabble when it becomes too hot, and replace it with a cold one. By lifting it out of the swivel fork, this is done without stopping the machine. The arrangement is such that the tool working on one side of the furnace cannot come into contact with the tool working on the opposite side, for as the one is going into the furnace on one side the other is making its outward stroke, and while one is working at the fire end of the furnace the other is working at the fire-bridge end. By an ingenious contrivance the machine causes the tool to work four strokes in each jamb before it returns on its journey across the furnace. The advantage of this will be seen when it is considered that the tool must pass over the middle of the furnace twice to reach alternately each jamb once. The furnace has water boshes around it to prevent the fettling from working out so rapidly as under the old arrangement of the single furnace. Messrs. E. P. & W. Baldwin, who have finished ironworks at Stourport, and Dudley, and Wolverhampton, are those who have most recently adopted the "Joe Pickles" furnace we have described.—*Engineer*.

RAILWAY NOTES.

Manufacture of Steel in France.—France, which at one time was reputed incapable of making steel, has made it at the following rates for the last twelve years :—In 1863, 1800 tons ; 1864, 6700 ; 1865, 9700 ; 1866, 10,800 ; 1867, 19,900 ; 1868, 42,600 ; 1869, 52,400 ; 1870, 90,000 ; 1871, 110,000 ; 1872, 138,500 ; 1873, 167,000 ; 1874, 217,000 tons. This extraordinary development of French metallurgy is encouraging to those interested in French industry.

An experiment is being made with wooden rails on a portion of the Muncy Creek Railroad, an unfinished line of forty miles, in Lycoming County, Pa. U.S. Mr. H. R. Mehrling, the superintendent, has recently had 700 ft. of track laid on a curve just beyond Muncy Creek, and it has been found to answer the purpose much better than was anticipated. The rails are of sugar maple, 7 in. by 4 in., and about 12ft. in length. The ties are laid down in the ordinary way, notched, and the rails let into them about 4 in. They are then keyed firmly with wooden wedges driven on the sides, which makes the track very solid and firm. The locomotive and heavy cars have been passed over this experimental track at different rates of speed, and it has been found to work admirably, and give every assurance of success. The cost of laying wooden rails, manufactured out of this hard material—that becomes almost as solid as bone when seasoned—is 450 dols. per mile. Iron costs 4000 dols. per mile. No iron spikes are required, as the rails are secured with wooden wedges, and the cost of track-laying is about the same as putting down iron. These wooden tracks have been tried at different places in the United States, and invariably been found to work well. The highest rate of speed for locomotives to pass over them with safety has been fixed at sixteen miles per hour, but even if this rate were reduced to twelve or to ten miles, the saving in expense would more than compensate for the reduction in speed. It has also been shown by experiment that these wooden rails will last, ordinarily, from three to four years, which is another important item to be taken in consideration.

A brilliant experiment in railway warfare has been conducted by Major-General Sir Charles Reid at Meean Meer. The *Pioneer of India* says its object was to test how guns and troops could be conveyed to or from any point of a railway line, independently of railway platforms and the usual accessories for the loading of heavy material. The General's method, described in a Calcutta contemporary, was as follows :—Doors, constructed to swing downwards, were opened in the front and rear of each wagon of a railway train. With all its doors down, the train became a long continuous platform, with high sides. At either end of this train was a low truck containing a pair of iron girders which could be readily run out, covered with planks, and converted into a sloping platform. Accordingly, at daybreak, half a battery of horse artillery was marched to the spot. The order was given to lower the doors and girders. The horses were brought in at one end of the train, and placed head to head, in their separate trucks, while the guns and the carriages were run up on the girders at the other ; the artillerymen were distributed in second class carriages ; finally, the girders and doors were pulled up, the engine was attached, and away went the half-battery on its expedition, in 36 minutes after its arrival on the spot. After a run of some minutes the train stopped at a place where there was a raised embankment, about half a mile from a level crossing. The doors and platforms were thrown down ; the horses went out at one end, and the Armstrong guns at another, and in less time than seven minutes the first gun opened fire from the embankment. It took only 45 minutes from the time the train stopped to limber the guns, each of which was pulled by six horses, and to reach the level crossing in full force and complete order.

ENGINEERING STRUCTURES.

Several civil engineers, engaged with the surveys for a water conduit from Touja to Bougie, have made a very interesting and important discovery. A mountain which was

situated in the proposed line of the conduit was to be tunneled for a length of 500 yards; and in searching for the most suitable place the engineer discovered an ancient tunnel 6 ft. 8 in. in height, and 19 ft. 7 in. in circumference. It is supposed that this is the same tunnel mentioned in an epigraph found at Lambeoc, according to which the tunnel was built in the reign of Antoninus Pius, the plans being prepared by a veteran of the Third Legion, named Nonius Datus. Finding works like this after a time of 2000 years, we cannot but be greatly astonished at the power, energy, and genius of a nation which produced, with the limited means available at those times, such gigantic structures.

WONDERFUL ENGINEERING.—Any one desiring to obtain any idea of the stupendous accomplishments of railroad engineering should spend a few days in Tehachape Pass, investigating the operations of the Southern Pacific Railroad Company. About twenty miles of that road is a succession of cuts, fills and tunnels. Within this distance there are thirteen tunnels, ranging from 1100 feet to a few yards in length. For the greater portion of the way the road bed is cut through solid granite. The elevation is so great from the present terminus of the road, at Caliente, to Tehachape Valley, that the first mile and a half out of Caliente is attained by laying down eight miles of track. Higher up in the pass the road runs through a tunnel, encircles the hill, and passes a few feet above the tunnel. After completely encircling the hill, and going half around again, the track doubles on itself like a closely pursued hare, and after running several miles in the opposite direction, strikes up the canon. This circling and doubling is for grade. Once the track crosses the pass, and this involves the building of a long and very high bridge. We doubt if a more difficult and expensive piece of engineering was encountered in the building of the Central Pacific over the Sierras than that with which the Southern Pacific is now struggling in Tehachape Pass. Another tremendous piece of work is the San Fernando tunnel, which, when completed, will be over a mile and a half in length, and in places over 1000 feet beneath the surface. Yet the company will accomplish this great work, and run cars through from San Francisco to Los Angeles by the first of next July. All the force that can be used is kept at work on the San Fernando tunnel. In the Tehachape Pass 5000 men are employed, and the force is being increased at the rate of 1000 Chinamen per week.—*Los Angeles (Cal.) Herald.*

ORDNANCE AND NAVAL.

THE work with the 81-ton gun, if it had been less important than others, has been of a more interesting character than any of its predecessors. In the first place the gun had to be lifted into its carriage, and it remained to be seen if it was properly adjusted. Of this the officials entertained no doubt from the care with which every part of both gun and carriage had been made to scale. The gun was lifted just as other guns are, by rope slings passed under its arms, or trunnions, and so well had their proper position been calculated that the monster hung in an exact horizontal line evenly balanced. The work of transferring it to its place on the carriage occupied only a few minutes, and it fitted, as anticipated, with perfect accuracy everywhere. Then came the more serious task of removing it down to or towards the butts, and for this work the locomotive which waits on the Royal gun factories, and is called the "Gunner," was brought into requisition. This locomotive, though much more powerful than the little engines which run about the Royal Arsenal on the narrow gauge, is not half the size of the ordinary railway locomotives, and doubts had been expressed as to its being equal to the duty required of it. Indeed, when it was first set to pull the great Juggernaut-like car along the railroad it was utterly unable to move it. Again and again the engine made the attempt, occasionally moving the wheels an inch or two, but more often pulling up dead, or snapping in twain the great hawsers by which it was attached. The character of the railway line had much to do with this failure; it was laid down a good many years ago for very different work. It is rough and irregular, and, moreover, it rises at first on a slight incline. By the help of lifting jacks, handspikes, and a rope attached to a stationary engine in one of the workshops, the carriage was coaxed on for about a hundred yards, but the 120 tons of dead weight resting upon its twelve wheels all packed close together was slow to move, and it was feared that the attempt must be given up for the day, or some other expedient adopted. It occurred, however, to some one to harness on a couple of the small locomotives in front of their larger brother, as the narrow and broad gauge lines run together. This proved the solution of the difficulty, for the three engines moved the burden quite easily, to the surprise of almost everybody, the additional power lent by the little engines being to all appearance ridiculously small. A stoppage, however, took place shortly before reaching the canal which separates the practice ground from the rest of the arsenal, and it was decided to defer crossing the bridge until to-day. Beyond the canal is the worst part of the line, as it runs along an embankment down a steep incline, which has on one occasion given way.

TORPEDO BOAT FOR THE AUSTRIAN GOVERNMENT.—MESSRS. J. THORNYCROFT, of Chiswick, have just completed a steam torpedo launch for the Austro-Hungarion Government. A trial of this boat took place on Saturday last, the 11th inst., on the Thames below London Bridge. At the trial trip there were on board, besides the builders of the vessels: Baron Spaun, Naval Attaché, Austro-Hungarian Embassy; the Vicomte de la Jour du Pin, Naval Attaché, French Embassy; and Mr. Schneider, Chief Engineer, Austrian Navy. A start was made a little below the Thames Ironworks at eleven minutes past twelve, and

the hour's run finished at Lower Hope Reach, below Gravesend, at eleven minutes past one o'clock. During the run the number of revolutions was taken by Mr. Schneider and Mr. Walker, chief draughtsman at Messrs. John I. Thornycroft and Company's, and was found to be exactly 24,700. The vessel was then run up to Long Reach, and run six times over the measured knot there, when the number of revolutions of the engines required to do one knot was found to be 1357. The number of revolutions done during the hour (24,700), divided by the number required to do one knot (1357), gave the number of knots done in the hour as 18,202, a result which is certainly most satisfactory.

On the way up to London the vessel was run past a small schooner at a speed of ten knots, and a dummy torpedo was launched against her side. The torpedo struck the schooner amidships at about 6 ft. or 7 ft. below the water level, and had it been filled with its charge of dynamite (25 lb.), the schooner would undoubtedly have gone to the bottom. The torpedo gear on this vessel consists of two poles 38 ft. long, one on either side, and so arranged that an attack may be made directly ahead of the boat, in which case the boat must be stopped and backed off her enemy immediately after the explosion ; or on the broadside, when the boat may be kept going ahead all the time, and so saving the time which would be otherwise lost in stopping and backing. The dimensions of the torpedo launch are :—Length, 67 ft.; beam, 8 ft. 6 in.; and the speed guaranteed by the builders was fifteen knots.—*Engineer.*

BOOK NOTICES

IVESON'S HORSE POWER DIAGRAM. London : E. & F. N. Spon. For sale by D. Van Nostrand. Price $4.25.

This is a folding chart to facilitate calculations of horse power of engines, when the ordinary data are given.

The results are found by line illustrations on finely engraved charts.

CLIMATE AND TIME IN THEIR GEOLOGICAL RELATIONS. By JAMES CROLL. New York : D. Appleton & Co. Price $2.50.

Mr. Croll has set forth his views at various times in the *Philosophical Magazine* and other British journals.

He is a vigorous writer, and has earned a right to respectful attention by his varied labors as a geologist.

The principal topic of the present work is the change in temperature of the earth's surface during geological ages, the evidence of which we find in the coal and drift formations.

The illustrations, consisting largely of colored charts, are very good.

HAND BOOK FOR CHARCOAL BURNERS. By G. SVEDELIUS, translated from the Swedish by R. B. ANDERSON, A. M. New York : John Wiley & Son. Price $1.50.

We presume this treatise may be considered of some value in some part of this country, though we don't exactly know where. Judging from the preface, the chief reason for the original publication in Sweden was a Government Prize of six hundred and fifty-six rix-dollars.

The author certainly made a good deal of one of the simplest operations in the world. The minuteness with which the details of the manual labor is described is equaled by nothing we know of except instructions for crocheting and needlework.

Charcoal makers, who desire to know how elaborate a process they are engaged in, should possess themselves of this work.

A MANUAL OF METALLURGY. By WM. HENRY GREENWOOD, F.C.S. Volume 2. New York : G. P. Putnam's Sons. For sale by Van Nostrand. Price $1.50.

The subjects treated in this volume are the extraction severally of Copper, Lead, Zinc, Mercury, Silver, Gold, Nickel, Cobalt, and Aluminum from their respective ores.

The work is systematic, giving the natural history of the different native compounds of these metals, and also their chemical constitution.

The reader is cautioned in the preface not to expect such a description of the details of metallurgical operations as only the larger works can contain ; the author only attempts to give such explanations as are generally received of the scientific principles upon which the processes are based. This he seems to have satisfactorily accomplished.

PROBLEMS IN STONE CUTTING. By S. EDWARD WARREN, C.E. New York: John Wiley & Son

Prof. Warren's works are so well known, that we need not enlarge upon their general excellence. From such inspection as we have been able to make of this work, we should say it was equal to the best of the professor's previous books.

We know of nothing so acceptable just now as this book. Having been called upon during the last season to recommend such a book as a supplement to a course in descriptive geometry, we were obliged to recommend parts of two or three expensive works as the only way of fulfilling the requirements. This new work of Prof. Warren's would have answered completely to the demand.

With his usual precision of classification, the author divides his problems into four classes; viz:

I. Plane-sided structures.

II. Structures containing developable surfaces.

III. Structures containing warped surfaces.

IV. Structures containing double curved surfaces.

Tin folding plates illustrate the work, containing seventy-three separate figures.

THE MECHANICAL ENGINEER: HIS PREPARATION AND HIS WORK. An address to the graduating class of Stevens' Institute. By R. H. THURSTON, A. M. C. E. New York: D. Van Nostrand. Price 50 cts.

It is well that this able address is put in a

form to reach beyond the circle for whom alone it was originally prepared. At the request of the hearers, it was published in neat pamphlet form.

The address may be read with profit by young and old of other professions than that of mechanical engineer.

The professor first details the nature of the studies pursued, and sets forth the advantages of the culture derived from each, then gives some exceedingly practical advice in regard to the use of the acquired talents in their professional career.

It is not a farewell speech of the ordinary academy or college type, but widely different in many respects, and naturally so, inasmuch as the graduates to whom it was addressed had presumably adopted a profession, and were entitled to advice regarding its duties. It is certain that no one was better fitted to advise them than their talented professor of mechanical engineering.

The Past and Future of Geology. By Joseph Prestwich, F.R.S., F.G.S. (An inaugural address.) London: McMillan & Co. For sale by D. Van Nostrand. Price $1.00.

From so eminent a source, an essay on the subject of Geological discovery is exceedingly valuable. Of course, the question of internal heat receives a large share of attention.

Several well executed diagrams, illustrating the distribution in time, of organic life, adorn the book and convey a surprising amount of information at a glance.

Sexton's Pocket-Book for Boiler-Makers and Steam Users. By M. J. Sexton. London: E. & F. N. Spon. For sale by D. Van Nostrand. Price $2.00.

This is substantially a table book of weights and dimensions of parts of a boiler. But brief treatises on the care and management of boilers are interpolated between the separate tables.

The book is neatly made, after the manner of the smaller table-books—opening lengthwise—is pretty well illustrated with wood-cuts, and moreover is furnished with blank leaves at different places throughout the book—a plan worth following in all similar works.

On the Strength of Cement. By John Grant, C.E. London: E. & F. N. Spon. For sale by D. Van Nostrand. Price $4.25.

This work gives detailed description of experiments upon the strength of cements; but chiefly on Portland cement, used in the southern main drainage works of London. The volume is a reprint of papers read before the Institution of Civil Engineers on two separate occasions: December, 1865, and April, 1871.

Besides the results of many experiments carefully tabulated, the plates afford valuable information to engineers respecting the construction of sewers of various sizes.

Homes and How to make them—Illustrated Homes. By C. C. Gardner. Boston: James R. Osgood & Co. For sale by D. Van Nostrand. Price $2.00.

These unique volumes ought to be widely read. They are designed primarily for those who are about to build, or who have friends soliciting advice about building houses; but they may be read with pleasure and profit by any who delight in lively pictures of home life amid people who are altogether human, mostly witty, and in every way agreeable to meet as the author presents them.

They are worth careful reading as samples of successful presentation of a semi-technical subject in a delightful way.

The Journal of the Iron and Steel Institute. Part 1. London: E. & F. N. Spon. For sale by D. Van Nostrand. Price $3.75.

Among the papers of this new volume, the more important are:

The Ores of Iron in their Geological Relations. By Warrington Smith, F.R.S.
Notes of a visit to Coal and Iron Works of the United States. By I. Lowthian Bell, F.R.S.
The Sum of Heat utilized in Smelting Cleveland Ironstone. (Same author.)
The Manufacture of Bessemer Steel in Belgium. By M. Julien Deby.
Reports of Iron and Steel Industries in the United Kingdom and in Foreign Countries.

The Works of E. Verdet: Cours de Physiquie. 2 vols. Leçons D'Optique Physique. 2 vols. Conferences de Physique. 2 vols. Theorie Mecanique de Chaleur. 2 vols. Notes et Memoires. 1 vol. Paris: Victor Masson.

Nothing in the way of wood-cut illustration or typography can be finer than is exhibited in these works of Verdet.

The volumes average something over 500 pages each. To illustrate the Cours de Physique alone there are 516 wood-cuts.

In Physical Optics this work is the most extensive with which we are acquainted. All are standard works.

A New Method of Obtaining the Differentials of Functions. By Prof. J. Minot Rice, of United States Navy, and Prof. W. Woolsey Johnson, of St. John's College. Revised edition. New York: D. Van Nostrand. Price 50 cts.

The authors of this little essay advocate a return to the method of *fluxions*, which has been almost abandoned by modern instructors.

The method of presenting the subject is certainly clear, and to the mathematical student attractive. Whether the beginner finds difficulty in accepting the doctrine of limits or not, he will certainly reap benefit from a study of this little treatise.

An Elementary Treatise on Steam and the Steam Engine. By D. Kinnear Clark, C. E. London: Lockwood & Co. 1875. For sale by D. Van Nostrand. Price $1.40.

We have here, recast, one of the series of practical works, presenting in a cheap and generally reliable form the elements and principles of science and art, and known as Weale's. The present work is adapted from Mr. John Sewell's elementary treatise on steam, the portions of that treatise, useful in its day, which time and discovery have rendered obso-

lete, being replaced by matter more directly interesting to the steam engineer. Other subjects, such as the mechanical theory of heat, unknown at the first publication of the work, are introduced for the first time, as well as the more important of the numerous improvements that the steam engine has received in the interval. The historical notice of steam and the steam engine, by Mr. Sewell, is retained unaltered, although susceptible of considerable improvement. At all events, such an obvious blunder as the representation of the goddess Isis as a male divinity, and the change of the termination of her name to suit the change of sex, might have been corrected. In the practical portion every essential part of the subject is treated of competently and in a popular style ; while there are also given numerous and useful tables illustrating the capacities of boilers, and the properties of fuel and steam.

Engineering Papers. By C. Graham Smith, Stud. Inst. C. E. Spon, London. 1875. For sale by D. Van Nostrand. Price $2.00.

This little work is a reprint of three papers on mortar, practical ironwork, and retaining walls. The first two were read before the Institute of Civil Engineers, and each obtained a Miller prize. The third was read before the Edinburgh and Leith Engineers' Society. We are pleased to see these papers put together in a convenient and accessible form, for they are very practical in their character, and contain a good deal of useful information. The paper on mortar is probably the best available treatise in the English language on the subject. That on practical ironwork is valuable, because it deals with the subject in a way hardly ever employed by other authors. Mr. Smith says little or nothing about strains, but he gives numerous practical hints about the way iron structures should be designed and put together ; and in a species of appendix to the paper he very properly calls attention to a fact too often overlooked—namely, that what are termed "fancy" sizes and sections of iron always command a fancy price. The designer should always endeavor to work with marketable materials ; but the student will search most books in vain before he can discover what sizes of iron are and what are not easily to be had at ordinary prices. The paper on retaining walls is simply and clearly written, but it does not contain much that is very novel ; indeed, so much has been written about retaining walls, that it is impossible to say anything new on the subject. We can recommend Mr. Smith's little book, especially to the younger members of the profession.—*Engineering.*

Designing Valve Gearing. By E. J. Cowling Welch, M. I. M. E. E. & F. N. Spon. For sale by D. Van Nostrand. Price $2.00.

This is a most useful text book, and something of the kind has long been a desideratum among draughtsmen and engineers. Valve gearing constitutes a rather difficult and perplexing problem, and the solution offered by scientific men in formulated results, is to the ordinary engineer only more perplexing still. Mr. Welch has conferred on the profession a great boon in this little book, in which he elucidates all the problems connected with the subject in as simple a geometrical manner as possible. In his opening chapter he gives the geometrical basis, viz., the 31st Proposition in the 3d Book of Euclid, on which his diagrammatic investigation depend. He then treats of the easy method in which the relative travel of crank, eccentric tumbler and slide valve may at any moment of the stroke be compared, and afterwards proceeds to treat of lap and lead, and adjustment of ordinary slide and expansion valves, for any ratio of cut-off. His further chapters on variable expansion valves, and on Stephenson's, Gooch's and Allan's link motion, are admirable, and invaluable to the engineer and draughtsman, who would wish to rise superior to the ignoble, but too frequent plan of valve designing by trial and model. There are but one or two little points in this most admirable text-book which we could wish altered for the better. The diagrams are excellent, and sufficiently numerous, but the matter is too heavily printed without break for convenient and comprehensive reading. The system of paragraphs, and special results being placed in separate lines, render such matter of much easier perusal and comprehension. Further, the book can scarcely be read with interest for general information. It is simply a series of propositions, since there is seldom half a dozen lines without reference to the diagrams. The diagrams are frequently not on the page in which they are being constantly referred to, and thus destroy all chance of consecutive reading. The book must be laboriously studied, like a book of geometry, but, nevertheless, is so well worth that study that we most heartily recommend it to all who may have valve gearing to design.

The Present Practice of Sinking and Boring Wells, &c. By Ernest Spon. London : E. and F. Spon. 1875. For sale by D. Van Nostrand. Price $3.00.

When the pollution of our rivers by manufacturing processes and the sewerage of large towns has risen to such a pitch that legislative measures are necessary to prevent widespread epidemical disease, it seems high time that some steps should be taken to obtain the supply of water for drinking purposes from some less feculent source. And it is not only in populous and manufacturing districts that such a precaution is necessary. In agricultural districts most of the supply is drawn from surface drainage or shallow wells, both becoming more and more unsafe owing to the increasing practice of dressing pasture as well as arable land with manure to an extent unknown but a few years ago. Under these circumstances it is well that deep in the bowels of the earth, especially in those countries where a wholesome supply is most difficult to obtain at or near the surface, there exist vast reservoirs of the pure element, which the improved engineering appliances of these days enable us to reach, and which, as in Liverpool, South London and elsewhere, have already been to a considerable extent utilized. To teach us to tap these stores in the best and

most economical way is the object of Mr. Spon's book. Suitability of site for a deep well depends mainly upon three considerations. First, there is the capacity and lie of the water-bearing strata, next, the extent of its outcrop, and, third, the amount of rainfall over the area of the outcrop. The presence and position of faults in the strata is another important element. Springs depend upon the rainfall, and that they sometimes appear independent of it is owing to the extent of the subterraneous accumulations which they drain. In deep wells where the water is collected from a surface much above the level of the well, the water, when tapped, especially at first, often rises with great force and to a considerable height. The secondary and tertiary formations, the last especially, from the alternations it presents of loose, sandy permeable strata with impervious rocks and clay, are the most suitable for deep well-boring. Some of the primary formations also are water bearing; but from the more general presence in them of bituminous, or other mineral impurities, they are less suitabe for water supply. The chalk —a secondary formation—is the great water-bearing stratum for the larger portion of the south of England. The greensand underneath it also contains vast supplies. In the midlands and northern counties again, the Permian and triassic formations yield immense quantities of water, and supply Coventry, Birmingham, and other large towns, copiously. Mr. Spon gives formulæ by which to estimate the probable supply in each case, furnishing also much varied and useful information applicable to numerous localities, which he follows up with an exhaustive practical exposition of the art and mystery of well-sinking, profusely illustrated, but through which it is difficult to follow him without the aid of his diagrams. We notice, however, no allusion to any of the numerous forms of diamond drill which have become so indispensable in all boring operations.

Some interesting information is given regarding the districts already supplied by wells in the strata above referred to. From the lower Permian sandstone large quantities of water are pumped for the use of Sunderland and many neighboring towns and villages. This supply, calculated to reach five millions of gallons a day, is obtained from an area of fifty square miles overlying the coal measures. Coventry is supplied with 750,000 gallons a day from two bore-holes driven from the bottom of the reservoir into the new red sandstone, the water rising at the rate of 700 gallons a minute. The wells of the Tranmere, Birkenhead and Wirral Waterworks yield together about four millions of gallons a day, drawn from the trias. Two million gallons of the water used in Birmingham comes from the new red sandstone. Crewe, Leamington, and Liverpool are supplied from the same formation. In 1850 the yield of one of the boreholes in the last-named town was nearly a million gallons in the twenty-four hours. The Goldstone wells, from which Brighton is supplied, are in the chalk, and each yields about 3,000,000 gallons daily.

TRAITE THEORIQUE ET PRACTIQUE DE LA FABRICATION DU FER ET DE L'ACIER, ACCOMPAGNE DUIN EXPOSE DES AMELIORATIONS DONT ELLE EST SUSCEPTIBLE PRINCIPALEMENT EN BELGIQUE PAR B. VALERIUS. Deuxieme edition originale Francaise. Royal 8vo, paper, with folio Atlas plates. Paris, 1875. For sale by D. Van Nostrand. Prlce $30.00.

This is the work of Prof. Benoit Valerius, who died May 30, 1873, now published from his MSS, and with considerable additions, by his brother, Prof. H. Valerius, of the University of Ghent. The text of this elaborate work forms a volume of 852 pages, royal 8vo. The plates are in portfolio, large quarto, and 35 in number, and are the finest as well as the most extensive series of drawings upon the subject that have ever been issued. Those covering the subject of roll turning are particularly noticeable in their elaborate character and fineness of execution.

APPLIED SCIENCE. Part 1. Geometry on Paper. Part 2. Solidity, Weight and Pressure. By EDWARD SANG. London: E. & F. N. Spon. For sale by D. Van Nostrand. Price each $1.25.

These two books are smaller than might be expected from their titles, but small as they are, they are quite disproportionate, on the side of bulk, to the amount of valuable information they contain.

Part 1 is a collection of examples in Plane Geometry, in which the pupil is advised to use very rude instruments; the diagrams suggest home-made ones.

Part 2 makes similar suggestions in regard to Solid Geometry, but adds chapters on Cube Root, Strains and the Steel Yard. The appearance of these apparent incongruities is explained by the author's opinion expressed in the preface, that the study of practical geometry must lead us to examine all the physical properties of matter which can influence our measurements or aid us in conducting them.

A TREATISE ON THE ORIGIN, PROPER PREVENTION, AND CURE OF DRY ROT IN TIMBER. By THOMAS ALLEN BRITTON. London: E. & F. N. Spon. For sale by D. Van Nostrand. Price $3.00.

Although the chief title of the book limits it to a consideration of dry rot in timber, the author has by no means confined himself to a consideration of this subject, but has devoted the greater portion of the volume to the descriptions of various established processes of seasoning and preserving timber and wooden structures, of the destruction of this material in hot climates, and of the decay of furniture, wood-carvings, &c. The first chapters, it is true, after the introductory remarks on the nature and properties of timber, deal with the question of dry rot, and besides describing its general characteristics and results, quote many authorities and give several illustrations bearing on the subject. Taken altogether the information is scarcely so complete as that contained in the article published by us last week (see *ante* page 151), and based upon the excellent treatise of M. Bourseul. After some consideration on the subject of felling and cutting

timber, the author proceeds with lengthy descriptions of various seasoning processes. Amongst them are Davison and Symington's desiccation method, Bethell's drying stoves, introduced between 1848 and 1863, Langton's patent for the extraction of sap, Kyan's bichloride of mercury process, the creosote treatment of Mr. John Bethell, Boucherie's sulphate of copper method, and many others tried in this country and abroad.

Coming back then to a subject more apropos to the title of the book, the author gives us a chapter "on the means of preventing dry rot in modern houses, and the causes of their decay." And under this heading we come suddenly to a receipt for killing rats, though what connection there is between these animals and dry rot, we do not at present perceive. Make a hole for the rats to come up, if they do not make one for themselves, mix a nauseous compound into pills and place it on the floor, with a number of saucers filled with water. The confiding nature of the rats will induce them to eat the compound before alluded to, which will make them so thirsty that they will drink till, like the sculptor in the conundrum, they "make faces and busts." "They can be buried in the morning," adds thoughtful Mr. Britton. To return to dry rot. Ventilation, pitching, and charring, are the best preventives fully pointed out by the author, who then quits his subject to dwell upon the æsthetics of house painting, but returns to it again finally and briefly as follows: "One cause of the decay of modern buildings and frequent cases of dry rot, is owing to the employment of bad builders." We are in error: for in closing this volume we find one more reference to the subject.

"In conclusion, we can only summarise our remarks on the cause of dry rot by saying 'season and ventilate' in every case. As to to the cure, that is not so easy to deal with. If the reader has ever had a decayed tooth aching, a friend has probably said, 'Have it out;' and we say, whenever there is a piece of timber decayed in a building which can be removed, 'Have it out and stop up with new,' and in so advising we are merely following the advice to be found *in a good old volume which has never yet been equaled.*" Here follow some verses from Leviticus. The italics are our own. The above extract will show that Mr. Britton, besides knowing all about dry rot in timber, has quite a happy way of communicating his knowledge. The publishers have done their part well in the preparatian of this volume.—*Engineering.*

MISCELLANEOUS.

Deep Silver Mine.—In Pribram, Bohemi, the Adalbert Pit, sunk in 1779, has reached in its present adit in the 1000-metre shaft the depth of 472.128 metres below the level of the Adriatic Sea.

Steel Rails in Italy.—The line from Rome to Ceprano, half-way from Rome to Naples, has been relaid with steel rails, the first result of which change has been to permit a higher speed of travel, resulting in a total saving of time on the journey of an hour and a-half.

The New Russian Gun.—The great Russian cannon, lately built at the works at Oboukowsky, has cost £13,000, and weighs 40 tons. It is a breech-loader, entirely in crucible steel, 20 feet 6 inches long; its largest ring is 57½ inches in diameter, and the tube has thirty-six grooves.

Light Hydraulic Motor.—An improved hydraulic motor for light machinery—a Swiss invention—consists of an oscillating engine within a water-tight casing, into which the water enters at one side and leaves at the other. The oscillating cylinder, driven by the water, swings in bearings, suitable entrance and exit ports of the bearing permitting alternately the entrance and discharge of water from the cylinder. The piston rod is pivoted to a crank disk of the driving shaft, and the power is transmitted by a friction cone and belting, and can be run at different speeds. The regulating air chamber secures uniformity of motion under various pressures. The casing is attached by screws at any suitable point near the machine to be operated, and the water can be conveyed by rubber pipes. No oiling is necessary, as the apparatus works entirely in water. It is said to be capable of from 120 to 500 revolutions per minute, with an average water consumption of 40 gallons.

Incrustation of Boilers.—This important subject has occupied the attention of the Paris Academy of Sciences. M. Lesueur, a telegraph inspector, sent a communication to the Academy setting forth the efficacy of zinc in protecting boilers from incrustation. M. Lesueur declares that in many instances the effect has been found excellent, the deposit being little and easily removed. It was asserted, in opposition, that in many cases, also, the zinc had failed entirely to produce the effect desired, and a quotation from Professor Knapp's "Chemical Technology" was read, in which the author states that, to the time he wrote, the pretensions of the advocates of galvanic action seem to be unfounded. It was recommended that the subject be entrusted to a committee for conclusive trials. A long list was given of the various substances which had been recommended for the preservation of boilers, such as a mixture of tallow, graphite and charcoal, of tar and oil, iron filings, broken glass, saw-dust, clay, alum, and soda mixed, potatoes, molasses, coarse sugar, chicory, trimmings of skins, sal ammoniac, chloride of barium, carbonate of barytes, and chloride of zinc.

As was stated before the Academy, the problem in question is a very complex one, and it is well that all should understand that it is not likely to be solved in a general manner. There can scarcely be any universal panacea. Water differs greatly in composition, and even the same water varies from time to time, so that the only chance of success in the adoption of an anti-incrustation medium would seem to depend upon a careful analysis of the water to be used, repeated at different seasons.

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BRIDGE AND TUNNEL CENTRES.

By JOHN B. McMASTER, C. E.

Written for Van Nostrand's Engineering Magazine.

II.

BRACING.

It is to be observed in connection with the matter of bracing, that the frames should be arranged in such wise that no piece suffers any strain other than *compression* or *extension* in the direction of its length. As it is, however, by no means an easy matter to make the distinction, we shall give the following rule to which there is no exception :

Suppose we have two beams abutting against each other at their upper end, and loaded at their point of intersection with a weight. Take notice of the *direction* in which this *straining force* acts, and *from* the point *at* which it acts draw in this direction a line representing by its length the intensity of the strain. From the remote end of this line draw lines parallel to the two pieces on which the strain is exerted. The line drawn parallel to one must of necessity cut the other or its direction produced. If it cut the *beam itself* the piece is *compressed*, and acts as a *strut*. If, on the other hand, it cuts *the direction of the beam produced*, the piece is *stretched* and acts as a tie. We may then lay it down as a general rule in framing, that if the piece *from which* the strain comes lies *within* the angle formed by the pieces strained, the *strains these* sustain are of the *opposite* kind to that of the *straining point ;* if that is *pulling*, they are pushing ; if that is *compressed* they are *stretched*. Again, if the piece from which the strain comes lies *within the angle formed by the direction of the two produced*, *all* will have the same kind of strain ; and, finally, if within the angle formed by the *direction of one produced* and the *other piece itself*, the strain will be of the *same kind* as that of the *most remote* of the two beams strained, and of the *opposite* kind to that of the *nearest*.

The object of all bracing, then, being to convert all transversal strains into others which act in the direction of the length of the beams, the frame must be divided into a number of triangles ; for as the triangle, or some modification of it, is the only geometrical figure which possesses the property of preserving its figure unaltered so long as the length of its sides remain constant, it is the figure best suited for structures in which rigidity is essential for stability. But, again, some forms of triangles are much to be preferred to others ; the strength of the pieces forming the triangle depending very much on the angle they make with each other. *Oblique* angles are to be

avoided. *Acute* angles when not accompanied by oblique are not so injurious, because the strain can, in such pieces, never exceed the straining force ; but in an *oblique* angle it can surpass it to any degree.

In all forms of bracing, too much attention cannot be given to the joints. Where the beams stand square with each other, and the strains are also square with the beams and in the plane of the frame, the common mortise and tenon is the most perfect joint, a pin usually put through both so as to draw the tenon tight into the mortise, and so cause the shoulder to butt very snugly. Round pins are much better than square ones, as they are not liable to split the bit. Where the beams are very oblique, it is difficult to give the foot of the abutting one such a hold as to bring many of its fibres into actual contact with the beam butted on. It would, in such case, seem proper to give it a deep hold with a long tenon. Nothing, however, can be more injurious, for experience has fully proved that they are very liable to break up the wood above them and push their way along the beam. For instance, suppose the head of an inclined strut abutting on a horizontal beam to descend a little; the angle with this latter beam is diminished, by the strut revolving round the stress in the tie beam. By this motion the bed of the strut becomes a powerful fulcrum to a very long lever ; the tenon is the other arm and very short. It therefore forces up the wood above it and slides along the horizontal beam. This may be prevented by making the tenon shorter,and giving to its toe a shape which will make it butt firmly in the direction of the thrust, on the solid bottom of the mortise. When the beam is a tie the joint must depend for its strength on the pins or bolts, and the iron straps placed across it.

STRIKING THE CENTRES.

Undoubtedly the most dangerous operation connected with the use of bridge centres is the process of striking them. No matter with how much care the arch may have been constructed, the drying and squeezing of the mortar will cause it to settle in some degree when the centres are removed, and this degree of settlement seems to be very largely affected by the time the centres are allowed to stand. By some it has been urged that the centring should never be removed until the mortar in the joints of the last course has had ample time to harden ; others going to the other extreme have advocated striking the ribs as soon as the arch is keyed, claiming, not without some reason, that the settlement of a *well built* arch will never be so great as to become dangerous even though the supporting frames be removed when the mortar is green. But possibly the best practice lies not far from either of these extremes. It has, indeed, time and again, been amply demonstrated that to leave the centring standing till the mortar has hardened, and *then* take away all support, the mortar having become unyielding, is to cause the courses to open along their joints. To strike the centre, on the other hand, when the arch is green will, seven cases out of ten, be followed by the fall of the bridge ; but by easing the centring as soon as the arch is keyed in, and continuing this gradual easing till the framing is quite free from the arch, the latter has time to settle slowly as the mortar hardens, and the settlement will be found to be very small.

It becomes necessary, therefore, to provide some arrangement by which the framing may be slowly lowered from the soffit of the arch, an operation accomplished in a variety of ways ; by folding or double wedges, by striking plates, by bearing irons and screws, by cutting off the ends of the principal supports, and, finally, by plate iron cylinders filled with sand. The folding wedges are, perhaps, most commonly met with in practice, and are finely suited for arches of small span, as a sill stretching from abutment to abutment may then be used to rest them on. They consist of two hardwood wedges, about 15 in. long, right angled along one edge, and placed one upon the other in such wise that the thick end of one shall be over the thin end of the other, thus making their surface of contact an inclined plane. These wedges are placed under the tie beam of the rib and on the sill, as is illustrated in Fig. 2. It is evident that by driving the upper wedge up along the inclined surface of the lower, the rib which rests upon the upper one must rise, so that

by placing a number of these folding wedges under each rib it may easily be keyed up to the desired level, and by driving the upper down the inclined surface of the lower, the rib may gradually be lowered. To keep the under wedge in place, it is usually made fast to the sill and the surface of contact of each wedge well greased with soft-soap and black lead. When the wedges are in place under the rib, it is a good practice to mark each wedge at the point where contact ceases, so that when the centres are being lowered we may be able to know whether they are lowered uniformly or not. For instance, let the lower wedges of three pair of folding wedges project two inches beyond the end of the upper ones, and mark with chalk on the *side* of each lower wedge the point where contact ceases; namely, two inches from its end. Now, if in striking the centres the upper wedges have *all* been driven back so that the *end* of each instead of being *at* the line is one inch *beyond it*, then the frame has been uniformly lowered ; but if some are one inch and some $\frac{3}{4}$ inch from the line, the frame has not been lowered uniformly, and the difference must be corrected by driving *all* the wedges till they are one inch from the chalk line.

It is evident that such an arrangement of folding wedges can be of but little use unless the horizontal beam or sill on which they rest is rigidly supported from beneath, as any yielding of the sill would be followed by a separation of the wedges and rib. In constructing bridges of wide span over creeks or rivers on which there is no navigation to be interrupted, it is usual to make use of the folding wedges and support the sill by a row of piles driven into the river bed, and it then becomes especially necessary to watch the wedges lest by some settling of the piles and sill they have separated in the smallest degree from the tie beam of the rib.

In cocket centres the folding wedges are replaced by a *sriking plate* placed at each end of the rib, and sustained by strutting or raking pieces which abut either on off-sets at the foot of the pier or on sills placed on the ground. Each plate consists of three parts, a lower and upper plate and a compound wedge driven between them. The upper of these plates is of wood made fast to the base of the rib, and is cut into a series of offsets on its *under* surface (see Fig. 4). The lower plate is likewise of wood cut into offsets, but on its *upper* surface, and is firmly attached to the raking pieces which sustain it. The compound wedge consists of a beam cut into offsets both upon its upper and lower sides so as to fit those of the two plates, and when driven between them is held in place by keys driven behind its shoulders.

Previous to the time of Hartley, the rib was struck in one piece by the use either of wedges or striking plates. To him, however, we are indebted for an improved system of striking or easing the centres by supporting each lagging upon folding wedges. When this arrangement is used the rib is firmly attached to its supports, and the laggings rest upon wedges placed between them and the back pieces of the rib. A great advantage gained by this, is that the laggings may be removed course by course from under the arch, and replaced if the settlement prove to be too great at any one part of the soffit. Another method, at one time much in use among French engineers, is to cut off the ends of the chief supports of the rib piece by piece, an operation which cannot be accomplished with much regularity, nor without much danger.

The least objectionable way of striking centres, and one accomplished with great ease and regularity is by the use of sand, confined in cylinders. A number of plate iron cylinders one foot high and one foot in diameter are placed upon a stout platform sustained by timber framing. The lower end of each cylinder is stopped by a circular disc of wood of an inch thickness fitting tightly into the cylinder, and at about an inch above this wooden bottom three or four holes an inch each in diameter are drilled through the iron sides of the cylinder and stopped with corks or plugs of wood.

Into the cylinders thus prepared is poured clean dry sand to a height of 9 or 10 inches above the bottom, and on this sand in each cylinder rests a cylindrical wooden plunger, which fits so loosely as to work with ease, and forms one of the vertical supports of the rib.

To prevent moisture getting at the sand, the joint between the plunger and cylinder is filled with cement. So long as the sand is dry it remains incompressible to any weight that may press on it, and the rib is thus kept invariably in its place. When the centre is to be lowered, the plugs are taken out of the cylinder, and as the sand runs out of each with *uniform* velocity the frame is *uniformly* lowered. This method is of especial value for centres of great weight.

The distance at which the frames or ribs of centres should be placed apart, measuring from the centre of one rib to that of the next, must be regulated solely by the weight of stone used for the arch, the distance varying inversely with the increase of weight. That is to say, if we assume some distance for stones of a given weight, say 6 feet for stones weighing 150 lbs. per cubic yard, and wish to find the proper distance apart of the ribs when the stones weigh but 120 lbs. per cubic yard, we have

$150 : 120 :: 5 : 4$. Then making 6 ft. the distance for 150 lb.,

$4 : 5 :: 6 : x \quad 4x=30 \quad x=7$ ft. 6 in.,

the proper distance for stones of 120 lbs. per cubic yard. The following table has been calculated in this manner:

Weight of Stone per Cubic Yard.	Distance apart of the Rib of Centring.
120 lbs	7 ft. 6 in.
125 lbs	7 ft. 3 in.
130 lbs	6 ft. 11 in.
135 lbs	6 ft. 8 in.
140 lbs	6 ft. 5 in.
145 lbs	6 ft. 2 in.
150 lbs	6 ft. 0 in.
155 lbs	5 ft. 10 in.
160 lbs	5 ft. 7 in.
165 lbs	5 ft. 5 in.
170 lbs	5 ft. 3 in.
175 lbs	5 ft. $1\frac{1}{2}$ in.
180 lbs	5 ft. 0 in.
185 lbs	4 ft. $10\frac{3}{4}$ in.
190 lbs	4 ft. 8 in.
195 lbs	4 ft. 7 in.
200 lbs	4 ft. 1 in.

It now remains to consider briefly, the subject of centring as used in the construction of the arched roofs of tunnels. In work of this description, the span being always small, the arch light and the facilities for obtaining firm points of support for each rib as great as can be desired, all the hindrances, that so often make the framing of a stone bridge centre a matter of no small difficulty and foresight, are wanting, and the rib admits of a simplicity of arrangement at once favorable to economy of material and of space. It must, however, be remembered that although the span is small and the arch light, the strength of the rib of a tunnel centre must be much greater in proportion to the burden it has to carry than that of a bridge centre; since the former has not only to resist the weight of the earth above it, but must also withstand the wear and tear of many destructful causes to which the latter is never exposed. In tunneling through a hill side, no matter how short the distance, more or less rock will invariably be met with, and more or less blasting must therefore be done, and the shock and flying splinters of rock which accompany each explosion do much mischief to the ribs by disturbing or injuring them. This cause acts strongly on all parts of the centre, but is especially severe with the leading ribs, which, as the brick work must always be kept well up to the heading, are directly exposed to the violence of each explosion.

A second cause of injury to the ribs, and one quite as damaging and unavoidable as the first, is the repeated taking down, carrying forward, and putting up of the ribs every time a length of arch is completed. In bridges, unless the structure is composed of a series of arches, the centring is never disturbed from the time it is first put up until it is finally *struck* on the completion of the works. In tunneling, however, to avoid the foolish expense of building centres from end to end of the tunnel, it is customary to construct but one length of twelve or fifteen feet of centring, and to move this forward whenever it becomes necessary to turn a new length of arch. Thus, for example, we will suppose that we are driving a tunnel through earth of a moderate degree of heaviness, and are, therefore, using centres consisting of two sets of laggings and five ribs, two made without and three with a horizontal tie beam. The object in making some of these ribs without the tie beam is that, by so doing, the centring may be brought close up to the heading without interfering with the raking props, which could

not be done were the beams to be retained. These five ribs are arranged in practice so that one without the tie beam shall be placed at each end of the length of centring, and between these two are the three with beams. We will suppose this to be the arrangement of the ribs in the present case, and will number them, beginning with that nearest the heading, 1, 2, 3, 4, 5. While the arch is being turned upon this length the excavation for a new one has been made, the invert built, the side walls raised to springing line and all is ready to carry forward the centring. This operation, however, must be done with the utmost caution. If the ribs are taken from under the newly completed arch before the invert and side walls of the advanced length are built, the whole piece of arch with its side walls will be almost certain to separate from the length just behind, and move forward several inches in the direction the work is progressing. If, on the other hand, after the advanced side-walls are up, *all* the ribs are taken from under the arch, this latter will be quite certain to come down in ruins, since it has to uphold not only the weight of the earth resting immediately upon its bricks, but, in addition, *half* the *weight of the earth* which presses upon the crown bars of the newly excavated length, as one end of all these bars rests upon the arch near its end. Rib number 1, then, which is directly beneath the end of the crown bars, can not be removed with any degree of safety. It is also desirable that number 3 should be left in place to help support the laggings. Numbers 2, 4 and 5 are the only ribs left, and these are to be taken down and set up forward, taking care that 5, which has no tie beam, is placed nearest the heading; the order of arrangement then being 5, 4, 2, 1, 3.

Over the rib thus arranged a second set of laggings is laid, and on them the arch is turned. When this length is completed, and all preparation made to carry forward the centring, the ribs numbered 4, 1, 3 are taken down and set up forward in the order 1, 3, 4, 5, 2, and so on till the centring reaches the end of the tunnel, or meets that coming from the opposite end of the tunnel, supposing it to be worked both ways.

Now, it is precisely this continual taking down and setting up of the ribs, that produces so much injury to them, since, in order to pass them under the forward ribs and props which remain standing, it is necessary to take them in pieces. Each rib, therefore, must be framed in such wise that it may be repeatedly taken apart and put together again without injury to its strength or to the joints of the timbers removed and replaced. Figs. 5 and 6 afford an illustration of two centre ribs arranged to meet these requirements in the simplest manner possible. Fig. 5 is a drawing of a leading or segment rib, which it will be observed is constructed without a complete tie beam at the bottom so as to offer no obstruction to the raking props. It consists of two parts or segments, which, when the rib is placed, join at the crown of the arch and along the line *a b*, and are made fast to each other by two iron bars placed across the joint at the crown, one on each side of the back-pieces, and bolted through the back-pieces as shown at *c c*. An additional band is passed around the two vertical beams as shown at *d*. To prevent any slipping of these beams along the joint *a b*, the surface of each beam is notched, as shown at *e*, and a wedge driven through the notch. When the rib is to be taken down, the band at *c c* and that at *d* is removed, and the wedge at *e* driven out, and the rib thus separated into two segments may be carried through a comparatively small space. As this leading rib is subjected to the direct effects of the blasts, and to flying fragments of rocks, its joints must be strengthened by irons placed on each side of the rib, over the joint, and bolted through the timbers as shown in the figure.

This form of rib is finely adapted for tunnel centring, as it may be taken apart without removing a single beam, while its joint is so arranged that the pressure of the arch assists in no small degree to hold its parts in place. Indeed, the only valid reason why this form of rib should not be used in every part of a tunnel centre is the absence of the tie beam, which is certainly a great security against the spreading or contracting of the span. Were this tie beam supplied, and it may easily be supplied by an iron screw rod, this form of frame would probably, in

addition to the convenience of taking apart and resetting, sustain any amount of pressure ever likely to occur either vertically or laterally, as also all ordinary wear and tear from use.

Fig. 6 represents one of the interme-

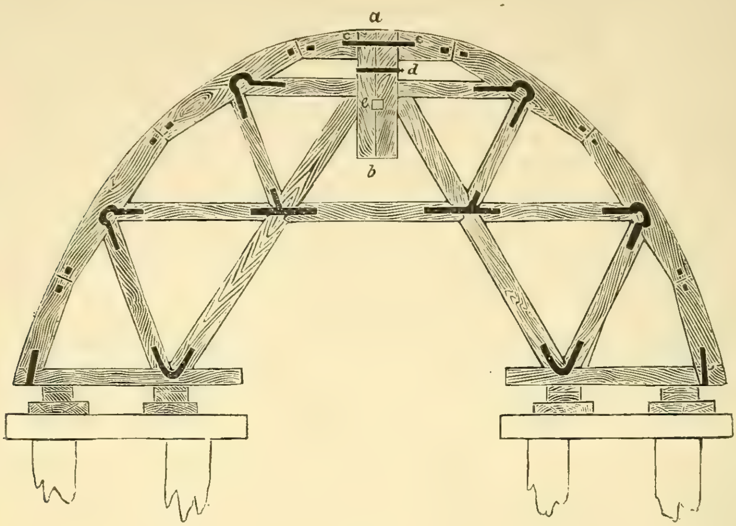


FIG. 6.

diate ribs called scarf or queen post centres, which, as there are no props to be interfered with, are provided with horizontal tie beams. As these ribs are also to be taken apart each time they are shifted, the tie beam is composed of two beams joined by a scarf joint strenthened by a piece of timber placed above it, and bound to the tie by two bands of iron as shown in the figure. The horizontal beam joining the queen posts is also movable, and is held in place by the iron placed over its joints and bolted through. In joints thus protected, the holes through which the bolts pass are liable after a time to become so much enlarged, from the repeated driving in and out of the bolts, so as to injure the strength of the joint. This may readily be overcome by using a bolt with screw threads at each end in place of a bolt with a head and one nut, so that when once driven through the beam it need not be removed.

By a comparison of these two forms of ribs, it is evident that while the queen post centre possesses an advantage over the segment form in that it is not liable to lateral spread, it is at the same time inferior to the former in many important points. It cannot so well resist shocks or side blows, and being so taken to pieces every time it is moved is very liable to be injured especially at the scarf joint. An additional recommendation for centres constructed on the plans of Figs. 5 and 6, is the small amount of material used, which is quite as small as is consistent with the varying strains the ribs are exposed to, and is so cut that the timbers are almost as valuable when the tunneling is completed as they were when first purchased for the ribs.

The estimation of the dimensions proper to give each tie and brace of the rib is easily determined in so simple an arrangement, by any of the methods given for bridge centres. It is, however, to be remembered that, while the bridge centre has to sustain but the weight of the arch stones and bonding mortar, a load which can be calculated to a pound before one stone is laid, the centring of a tunnel has to resist the pressure not only of the brick roof, but also of the earth above, and that this latter pressure is wonderfully variable. The pressure of the brick work will of course vary when laid in cement and when laid in mortar. From the most careful experiments made to determine the weight of a cubic yard of brick work, we find that when the

bricks are laid with cement the weight per cubic yard is 2,897 pounds, or in round numbers 2,900 lbs.; when laid in mortar beds the weight falls to 2,677, a difference of some 220 lbs. per cubic yard. It is true that the pressure of the earth does not act to any great extent on the centring, until the arch is turned and the crown bars drawn forward to form the roofing of the newly excavated length, but when this is done, and the three ribs removed to be set up in advance, the pressure on the two ribs remaining under the arch is quite severe. This load is especially variable with the leading or segment ribs, which it will be remembered are placed at the ends of the length of arch, and sustain one end of all the side and crown bars supporting the earth, and the movement which this earth is at any moment liable to take, cannot be foreseen. At times a whole length can be gotten out and the arch turned without any perceptible motion of the earth either at the sides or on top; at others, the earth will of a sudden begin to move and throw all its pressure on the side bars; then, again, the action will take place at the crown and become so great as to press the bars down in the middle through a distance of many inches, or even to break the stoutest 15-inch oak beams.

This action of the earth, however, seems to be controlled by law, since it depends largely on the depth of the tunnel below the surface. The pressure on the sides is most severe in those parts of the tunnel which are deepest, and the vertical or crown pressure (and this is always the severer of the two) where the distance below ground is less. At first thought this is precisely the reverse of what we should expect to be the case, for it seems but natural to suppose that the greater the depth of earth the greater the pressure on the arch beneath. The facts are, however, quite the contrary. Thus, for example, in excavating a tunnel through a hill, as we enter the hill side the pressure is almost exclusively at the crown and very severe; as the work progresses nearer and nearer the centre of the hill where the amount of earth above the arch is greatest, the vertical is changed to lateral pressure, and this latter is in turn changed to vertical as we approach the other end. This is well accounted for, by supposing that in the former case the depth of earth being small, the whole of it gets into motion and acts vertically downwards, while in the latter case the amount of earth being great only a small portion is put in motion.

The leading rib, then, must be constructed with no small care, and its joints well strengthened. For tunnels of ordinary span, whatever may be the curve of soffit, we may with safety give the parts the following dimensions. The backpieces two thicknesses of 3 in. plank; the planks breaking joints with each other. For the segment rib make all the braces 6 in. $\times$ 6 in.; the long struts reaching from the half sills to the crown 7 in. $\times$ 6 in., and the vertical pieces at the crown forming the joint $a\,b$ also 7 in. $\times$ 6 in. For the queen post centres, make the tie beam 9 in. $\times$ 6 in., as also the short timber placed over the scarf joint; the queen posts 6 in. $\times$ 6 in., excepting at the upper and lower ends where the braces abut which should be $10\frac{1}{2}$ in. $\times$ 6 in.; the short piece between the queen posts, and just below the crown 4 in. $\times$ 6 in., and, finally, the braces 6 in. $\times$ $5\frac{1}{2}$ in.

The manner of setting the ribs is illustrated in Figs. 5 and 6. Under the queen post ribs is placed a long horizontal beam, its two ends resting on the side walls and supported immediately under the foot of each queen post by vertical posts. Upon this beam are placed longitudinally four thick planks, and on these rest the folding wedges. The segment ribs are supported in much the same way, each rib by two short timbers, one end of each resting on the side walls and one on a vertical post under the heel of the rib; on these rest the longitudinal planks which are placed, however, a little oblique to the tunnel since the heel of the segment rib is not so far from the wall as the foot of the queen post.

It has already been remarked that it is never wise to strike the centres until the side walls of the newly excavated length are up, as in work of this class there is a strong tendency to move forward in the direction of the excavation. If, however, the ribs are struck in the manner already described, with the laggings of the back length kept tight up to the arch by the two frames left under

them, we shall always have two lengths of completed work remaining with their supports, not only until the next length is excavated but till the side walls are built and ready for the ribs. Under such circumstances each length is well able to uphold its burden till it receives assistance from the next advancing one, the construction of which to springing line occupies several days, and the cement or mortar has time to harden before the weight comes upon the arch after striking the centring. When, however, from false motives of economy, only three ribs and one set of laggings are used, the entire support of one stretch of arch must be removed before another can be commenced, and this, again, before a third is turned, leaving the green arch unsustained, in which state it is liable to give way, the bricks to crush and the whole arch to come down in utter ruin. Nowhere, indeed, among all the variety of engineering works will a penny wise economy more surely prove a pound foolish one than here; nowhere else will an unwise saving lead to so profuse an outlay.

Tunnel centres again differ from those of bridges in that the laggings are very differently adjusted. In the later case it is the custom in practice to place all the laggings on the ribs before commencing to turn the arch, by which means no small degree of stability is given to the ribs. In tunneling, however, where only a few inches of space remains between the backpieces of the frame and the poling which sustains the earth, it would be utterly impossible to turn the arch if *all* the laggings were put in place before the brickwork is begun. To overcome this difficulty, only a few laggings, say five or six are placed at a time. Thus, starting at the springing line, we adjust six laggings on each side of the frame, and carry the arch up equally on both sides. When it has reached the upper bolster, we add six more, and the masonry continued as before, and proceed in this way until very near the crown as shown in Fig. 7, where A A′ is the brick

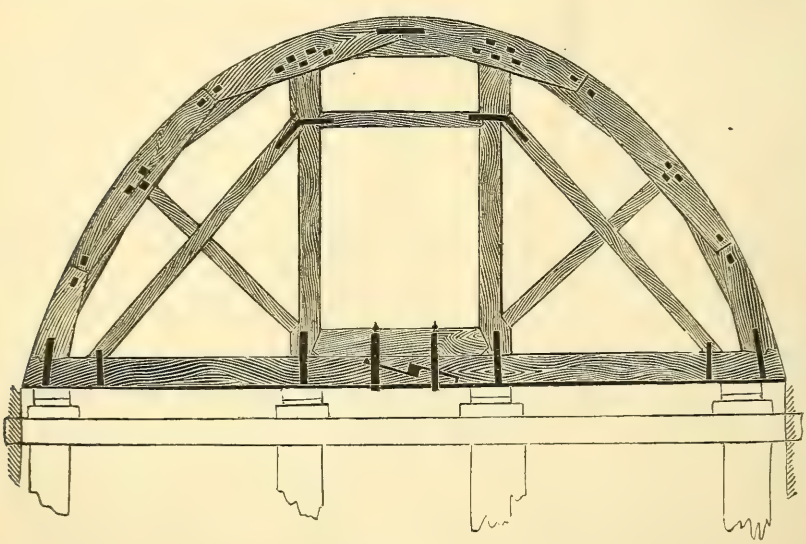


Fig. 7.

work. At this stage of the work the two laggings C C′ are placed on the ribs, the top of their inner edges being first rabbeted as shown in the figure. In these rabbets "*cross*" or "*keying-in*" laggings B, consisting of stout planks 18 or 20 inches in width, are laid one at a time beginning at one end of the centring. The bricklayer whose duty it is to key-in the arch stands with his head and shoulders between the brickwork A, A, and starting at the end of the last piece of completed arch places the first *cross* lagging, and keys in the arch over it; then a second, and in like manner keys in the arch over it, and thus re-

treats along the entire opening until the whole length of arch is keyed in.

Among the varieties of patent centres that planned by Mr. Frazer, affords a most excellent specimen, and both from its strength, economy, ease of shifting and the small amount of space it occupies in the tunnel, has met with much approval from the engineering profession in England. This centre consists of but three ribs each differing from the other two in design as shown in Figs. 9, 10

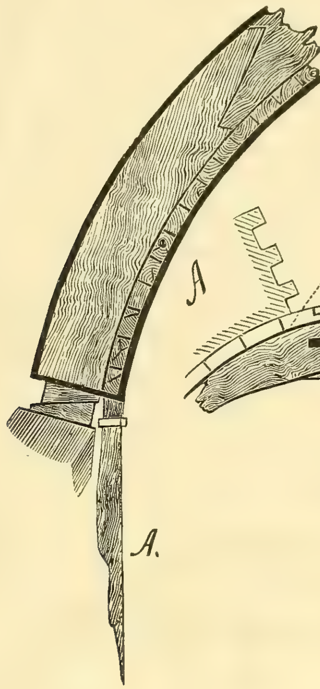


Fig. 9.

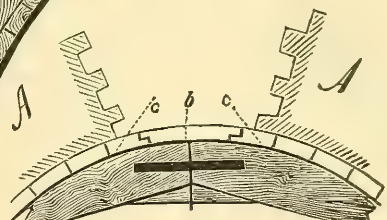


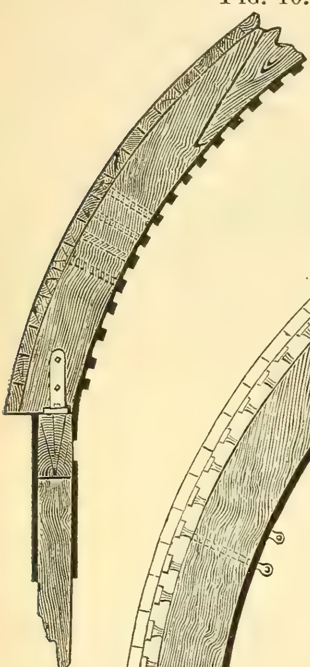
Fig. 8.

and 11, of which 9 is the leading, 10 the middle and 11 the back rib. Each rib is constructed of four pieces of timber four and one half in. thick by 16 inches wide, scarfed together as shown in the drawings. In centres of the ordinary construction, the ribs when the laggings are laid upon them are all of precisely the same size, and of the same span and rise as the soffit of the intended arch. In Mr. Frazer's plan, however, all the ribs differ in the length of their radii; the radius of the outer curve of the leading rib (Fig. 9) being greater; that of the middle 3 inches less than, and that of the back rib yet smaller than the radius of the soffit; so that the middle centre is the only one of the three which acts in the same way as the ordinary centre frame, that is to say with the laggings and arch resting immediately upon the rib, and is consequently with the laggings on it of the same rise and span as the arch.

The leading rib has for its outlet edge a radius $12\frac{1}{2}$ inches larger than that of the arch soffit, and for its inner edge one $3\frac{1}{2}$ inches less than the same radius (thus making the 16 in. thickness) and is plated on both the inner and outer surface with half inch iron plates bolted quite through. The plate on the inner surface is six inches broad and projects 2 inches over that side of the rib which is turned towards the middle rib, thus forming a flange on which the laggings rest (see Fig. 9). When this rib then is in place, it must be its whole thickness in advance of the end of the intended arch, and as it stands $12\frac{1}{2}$ inches above the soffit will cover $12\frac{1}{2}$ inches of the toothing ends of the brickwork, thus forming a sort of mould to guide the toothing.

The middle rib (Fig. 10) is also covered on the under surface with half inch plate iron in one piece and bolted through as shown in figure, thus giving the rib the strength it would have if supported by the usual struts and braces. The laggings rest immediately upon the upper surface of the rib, and therefore the radius of this side must be the same as that of the arch soffit, less *three inches* to allow for the thickness of the laggings.

FIG. 10.



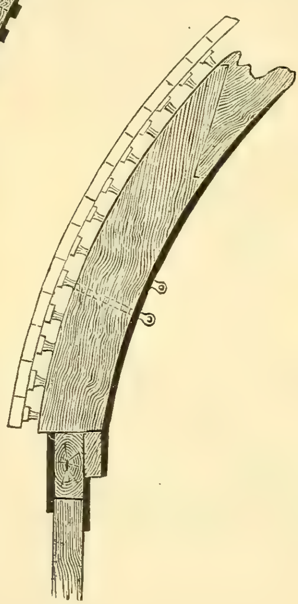


FIG. 11.

The back rib (Fig. 11) is covered on the under surface with a coating of half inch plate iron in one piece, which is bolted through as in the case of the middle rib. Between each bolt a hole is made quite through the rib and its plating, and in it is placed the stem of a bearing iron. There are as many of these irons as there are laggings, the object of using them being to support the laggings which it will be observed do not rest on the rib but on the projecting irons. The amount of projection is regulated by means of adjusting screws, by screwing which the laggings may be raised to the required level, or by unscrewing lowered one by one from the arch when completed. These last two ribs are permanently attached to trestling by brackets, straps and bolts, and the trestling in turn mounted on iron rollers which run on half timbers laid longitudinally as a kind of tramway. They are also steadied at the crown by long iron hooks attached to one rib and fitting into eyes in the other.

The leading rib is supported upon slack blocks placed on top the brickwork of the side walls and by the prop A. This prop, to allow for any inequalities of the invert on which it rests, is mounted at the lower end on a screw by which it may be raised or lowered.

In setting this patent centre, the leading rib is first brought forward into place and wedged up on the edge of the brickwork to its desired level, and the prop A screwed up tight under the heel. The trestles bearing the middle and back ribs are then rolled forward till the middle rib is at the proper distance from the leading one. Three pairs of wedges are then placed between the bottom piece of the trestles and the tramway, and the trestles thus wedged up until the top of the middle rib is on a level with the flange of the leading one, thus giving two level bearings for the laggings. The bearing irons of the back rib are then pushed out by the adjusting screws until the top of each of them is also on a level with the flange of the leading rib. The three bearings then, of each lagging, when the ribs are thus arranged is first upon the flange of the leading rib, then upon the middle rib itself, and finally upon the bearing irons of the back rib. When this centre is to be again moved forward on the completion of this length of arch, a fourth rib called the "*jack rib*" is first fixed under the laggings in the rear of the back rib, this last named rib consists simply of a band of iron 1 inch thick by 2½ wide, bent into the shape of the arch. Opposite every alternate joint of the laggings a screw passes through the rib, and is furnished on its outer end with a square head similar to that of the bearing plates of the back

rib, and on its inner or lower end is a loop so that it may be easily turned with a lever. The object of placing these screws opposite each alternate joint is that by this arrangement only half as many screws are needed as there are laggings. The jack rib is itself supported at each end by an iron bar 2 feet long driven temporarily into the wall.

As soon as this latter rib is adjusted to take the ends of the laggings, the wedges are driven from under the trestles and its rollers thus brought down upon the tramway prepared for them. When thus lowered, it is evident that the two ribs (middle and back) will be so much below the leading rib which is left standing that they will easily pass under it. The trestle and its ribs is then moved forward until the back rib is within 8 inches of the ends of the laggings, when it is wedged up as before. The bearing screws are then screwed up tight against the laggings, giving these latter the same support hitherto obtained from the leading rib, which now stands between the middle and back rib. The wedges under the ends of the leading rib (see Fig. 9) are then removed and the rib carried forward over the top of the middle rib and adjusted, as previously described, on the top of the newly built side walls. The laggings are then drawn forward one or two at a time as they are needed, beginning at the springing line.

The great advantage which these patent centres appear to possess over those of the ordinary construction, is the total absence of all struts, ties and braces, thus leaving a fine open space for the scaffolding and materials of the masons. The amount of repairs also is very trivial, as they are not so liable to be injured by flying rocks. In point of economy, though the first cost of patent centres is much greater than that of the segment or queen post centres, the amount expended in repairing the latter soon makes up the difference. In point of strength, it must be acknowledged that, when working through heavy earth, the patent centre of three ribs is by no means so reliable as the all-wood centre of five ribs and two sets of laggings, used as above described. And this is certainly a serious objection in that, it is impossible to tell beforehand at what moment, owing to a fault or to the displacement of the local beds, the character of the earth may change completely from a light soil to one of great heaviness.

EMBANKMENTS AND RESERVOIRS—THEIR FAILURE, AND SUGGESTIONS FOR THEIR CONSTRUCTION.

From "The Building News."

We alluded sometime ago to the recent calamitous failures in the south-western districts of England, occasioned by the late floods ; and we hinted their cause and remedies. The great importance of the subject urges us to revert to the question, to recall some of the weak points and to discuss the modes of construction usually adopted. A great diversity of opinion exists among engineers as to the mode of construction—so great indeed, that every engineer has his peculiar views of what should be the form and the materials adopted. A variety of considerations should determine in each case, the plan, form, and materials of embankments. They have to sustain the depth or pressure of water, to withstand the abrasion caused by the normal condition of wind, waves, and tidal currents. The materials along the locality of the coast or river have to be used to the best advantage, and the cost of land and maintenance must be considered. Again, long slopes towards the water offer least resistance to the action of the currents, and are less liable to injury, than more vertical ones ; on the other hand, they are more costly in the area of land they occupy, and in the amount of material required. They also do not impose so effectual a barrier to the waves of the sea, or high tides and floods. Slopes of steeper inclination, or

vertical faces, expose less surface to the action of the water: they occupy less ground, and cost less in material; though, on the other hand they have more direct pressure to sustain, and there is a greater re-action. The hydrostatic law that the lateral pressure of a liquid is perpendicular to the side of the enclosing walls, and is equal to the weight of a column of the liquid whose base is the side and height equal to the depth of the centre of gravity of the side—is one that has to be constantly kept in view in designing the embankments of reservoirs and canals. Under general circumstances—that is to say, excluding the effects of the waves—the depth of water only, not its expanse or area, has to be taken into account in proportioning the thickness of embankments. It is as easy to embank a foot or a few feet depth of the Atlantic, as it is to embank a canal of the same depth, the difference being in the former case there would be more wave force and abrasion. The same lateral pressure exists in both cases. Let us here speak first of the forms and materials of river and coast banks, and secondly of tidal action and currents. Engineers differ greatly as to the best kind of slope. In reclaiming fore-shores from the sea, the banks are made from 3 to 4 or 5 ft. above the high water of the spring tides, their width being 4 ft. to 7 ft. at the crown. These banks are best curved to a convex form to the water, and no angular or sharp projections should be allowed. In Holland, the sea slopes are generally inclined slightly to the horizon, or made as flat as possible. It is evident this is a question that must depend mainly on the material and the area of enclosure. Col. Emy, an authority, has advocated a section of bank in which the slope is concave as the best to resist the action of the waves. Others prefer straight slopes, as the angle of repose of the material. In flat slopes, sand and silt may be made available, and, as we have seen, such slopes offer less resistance to the tide. Tidal action is greatest at the lowest high tides of the neaps. For inner slopes, the Dutch, who have great experience in these works, made the batter about 4 or 5 to 1.

The fascine banks of Holland may be noticed. Brushwood twigs of about 4 in. diameter are tied by others at intervals. These fascines are from 8 to 13 ft. in length, of about 1 ft. 8 in. girth, the small and large ends being placed together alternately. In other cases the fascines are placed horizontally, the ends of one layer being successively within the lower one so as to form a slope, the whole being tied by stakes driven through each, which are hooped round at the head. Sand, clay, shingle, or gravel, is rammed between each layer. A batter of $\frac{1}{3}$ or 1 to 1 in height is given. In many parts of our country, as in Wales and the North, rubble facing should be used as the cheapest and best material. The stones should be larger and be laid to a slope of $1\frac{1}{2}$ or 2 to 1; or the banks may be pitched at that part subject to erosion. Such partial facings must have solid earth or clay foundations, but we prefer loose rubble at the lower angle. A double row of piles is a good protection to the feet of these banks, with loose stones rammed between and in front. Long slopes require the least thickness of pitching. In timber districts, where rubble is costly, the banks may be protected by timber or plank facings. The guide piles are driven slightly inclined, whaled at the top, and planked horizontally inside, the earth being rammed against the planks. Occasionally diagonal piles are driven in the bank to help the piling. The Piedmontese engineers use a temporary defence of sloped piles supported by strutting and planked against the water. But the use of concrete as a substitute for stone or timber must eventually become general. A concrete backing faced with rubble, or dressed to a batter, makes a good and impermeable defence. In the Medway it has been adopted with success, and its cost is such that, wherever local materials are wanting, it offers the best alternative.

One fertile source of floods in lands enclosed by these banks is the difficulty in discharging the water during variable states of the tide, owing to the sluices of the outfall drains being closed by the head of water against them. These sluices should be of such area and frequency as required by the propable contingencies of tide, and should be hung so that the pressure of the land waters

may readily open them. We believe half our reclaimed land is deluged on account of inadequate provision in this way. A sluice of eight feet wide to 60 or so acres is considered sufficient, and we think a sluice working on a vertical axis shutting against a rebate, and having the axis fixed so as to make unequal openings to prevent the tidal water from entering under pressure, is one of the best kinds. In all tidal rivers like the Severn, it is of frequent occurrence that the mouths get choked up by the rising of the tide for a considerable period ; and, when this takes place at the time of heavy storms, the danger of inundations is imminent.

The action of waves is another great cause of disturbance to embanked lands. On the coast of Scotland the fury of the Atlantic produces an average pressure, Mr. Stevenson found, of 611 lb. per square foot ; and on seacoasts this must be added to the depth-pressure. Concrete blocks alone seem to withstand this action, which is greatest at half-tide. Slopes help much to diminish the impetuosity and power of waves, and we may take the section of the Plymouth Breakwater as a good type of construction.

The Dutch dykes may be taken also as good examples ; in some of these, the body of the embankment is of earth, with a core of fascines and with a facing of rubble.

Puddle between sheet-piles, or an earth bank behind vertical sheet-pile facing, is sometimes adopted. A good plan is to form a loose rubble core in the water slope with rubble at the base. When sheet piling is used, inclined piles driven into the embankment or shore, to resist the pressure, may be desirable. One necessary precaution in vertical sea-walls which more effectually resist the action of waves is a good impervious foundation, as we have before said. The waves in this case have the effect of undermining the defence, and therefore the footing should be well-founded and consolidated. The bursting of the Holmfirth reservoir in 1852, when 100 lives were suddenly lost, arose from a leakage or spring in the seat of the embankment ; and the Bradfield reservoir failure, still in the recollection of our readers, was simlarly undermined through insufficient puddling. The crowns of embankments are, as a rule, not carried sufficiently high to resist unusual floods, and the water, once it gets the upper hand, soon softens and disintegrates the bank, disturbing the backing and causing settlement. There are some points, too, that require higher banks than others, as when a sudden bend occurs, or a confluence or eddying of currents exists ; and for this reason it is imperative that the character of the sea-coast, or the general curve of the river, should be preserved in the outline and section of any artificial embankments. Sloped banks increased the ascensional force of currents impinging on them, and this we know is not taken into account as a rule. Such banks should, therefore, be made higher than vertical or abrupt banks. There is a certain angle of surface with the horizon at which this rise attains a maximum.

The law of tides, as derived from astronomical theory, is considerably modified by local and other disturbances, as the configuration of the coast, winds, &c. ; and frequently the neap or quadrature tides rise as high as the spring tides, or those happening at the syzigies. Thus we know, from personal observation, that on the coast of Hampshire the neaps occasionally equal the spring tides in height by the action of gales. Again, the sectional form of coasts increases the height of the tidal flow where it rises higher than in the open sea.

At Chepstow, the spring tide is said to rise 60 feet, and at Bristol 40 feet, while in mid-ocean islands it is not perceptible. Rivers form capillary-like funnels, which augment the height and duration of flood-tides along their flow, and thus we find them dangerous inlets when banks are low, or the natural level of the river is nearly on a par with the adjacent country. At Southampton, Christchurch, and some other places, a double tide is experienced. The double tide of the Southampton Water is a remarkable instance of the return or ebb tide being met and driven back by the larger tidal wave which flows up the wider channel of Spithead. Thus the smaller current, which is a branch of the great Atlantic wave, loses its velocity along the Western side of the Isle of Wight, and at its fall down the estuary of Southampton is met by the great-

er weight which proceeds up the wider or Spithead entrance on the eastern side of the Isle of Wight. While affording admirable facilities for ocean steamers leaving Southampton docks, by delaying the fall of the tide, this double tide acts with fatal power in low-lying districts by blocking up the outfall of the fresh storm and land waters. Colonel Emy has noticed the "bore," or the interference of the tidal wave by contractions or bars in the beds of rivers. It is really a similar meeting of waters, causing a sudden rise at a certain point; and in the Severn, along which the floods have done so much damage, this rise is considerable. But the ordinary cause of flooded districts is owing to the opposite flow of the land waters and the tide. They meet somewhere in the river, and if the volume of outflow happens to be great, the rise of the water in long rivers is considerable, and the effects disastrous. Having spoken of the action of the tide, let us briefly refer to the effects the currents of rivers have upon their banks and beds. An erosive action is constantly going on in one part or another. In steep parts, the tendency is to deepen the bed, and the excavated detritus is deposited in creeks and bays or in sudden bends, tending to fill these up. Again, in the outfall portions of rivers, the silt or sand is spread over the bottom, for the velocity is diminished, and the power of transporting materials is less. Thus we have the delta of the Mississippi causing the mouth to be silted up. The banks of a river of ordinary flow corrode more than the bottom, and here we find the greatest irregularities and deviations in most of our rivers. We also find, in observing our river courses, that a resisting bank on one side produces a concavity on the other bank. An obstruction, or sudden projection, similarly, has the same abrasive effect, the stream turning against the opposite shore. Again, we find the river deepest along the steepest bank. Along a concave bank, the stream deepens the bed, and the silt is deposited on the convex side.

By a system of impervious banks we increase the scour, and, therefore, the depth of a river. Planting willows or osiers along the banks of wide rivers, so as to give them an equal width of waterway has had a good effect; banks are formed by the deposition of the sedimentary matter and sand round the roots. In a like manner, a species of groins or spurs placed at right angles or obliquely to the stream, is sometimes used, but longitudinal banks are least expensive and most effective in their action. The penned-up lands should have waste weirs to allow the freshets to escape, and, we imagine, in some of our inundated districts the outfalls have been insufficient for extraordinary storm-waters. We may here briefly refer to a very important point affecting the safety of our water defences—namely the formation of shoals. At the junction of streams or rivers shoals frequently occur owing to the difference in the specific gravities of the fresh and salt water, to velocity, and other disturbances. The deltas of our great rivers, arising from the deposit of alluvial matter at their mouths, diminished velocity, and interference of the outflow by the tide, are instances of obstructions. Mrs. Somerville, in her admirable work, notices the interference of the outfall of main streams by increased freshets. The Rhine was once reversed in its flow by this cause, and the Mississippi is much subject to interference in its flow by the Ohio. Alluvial deposits between the latter rivers have formed an elongated island, and attempts have been made to build a city upon it. In placing a dam across a stream to close it, it is found that the best situation for it is not at the embouchure or point of junction, but at some distance above, so that the deposits may render it impervious. These deposits occur by reason of the stream becoming stagnant before reaching the dam. Submersible dams, made by filling caissons with stones or gravel and sinking them, may be frequently employed with great effect, for by contracting the waterway it is deepened proportionately. Sunken dykes have been employed in the delta of the Mississippi with signal improvement, and after dredging and other means have failed. We only point to these instrumental measures as useful in their bearing upon the subjects of embankments; for we think that to dam a brook or a valley, or to embank a stream just where convenience dictates, is often to open to the insidious foe miles of assailable districts and undefended banks.

PUBLIC WORKS IN EGYPT.

From "The Engineer."

It is only within the last half century that engineering works in Egypt have been promoted and constructed in a manner which promises well for their future permanency and the real interests of the country. Long previous to the time alluded to, engineering works of enormous magnitude rivalling those constructed in India during the dynasties of the Abdallahs and the Aurengzbes, existed in Egypt, but with the exception of the Pyramids but little remains of either their former grandeur or utility. With the decadence of the cities, the pleasures and wants of whose inhabitants they were intended to minister to, they fell into disuse, and shared in the general destruction and desolation which ages ago swept over that portion of the African continent. But although the nature and extent of these great works of construction can now be but guessed at by the light of some stray excavations here and there, and their successors bear but little resemblance to them in either design or execution, yet the physical condition of the country remains unaltered. Rightly or wrongly, the origin of surveying—one of the branches of our profession—is attributed to the necessity which compelled the Egyptian landowners to define their properties by some boundaries which were not liable to be obliterated by their annual natural floods.

As of old, so at present, the ever-recurring periodical overflowing of the Nile constitutes the natural phenomenon of the country. From time immemorial the efforts of the monarchs and the people have been directed towards the one great object—viz., that of regulating and rendering uniform, and turning to the best advantage, the fertilizing inundations of this mighty and mysterious river. Probably the idea and attempt also to unite the waters of the Mediterranean and the Red Sea may boast of the same degree of antiquity. The Nile being thus the most important and, in a great measure, the sole source of the prosperity and wealth of the country, it is evident that works of irrigation, and others undertaken with the object of improving the course and condition of the river, must constitute a prominent feature in Egyptian engineering. In Upper Egypt some extensive works of this character were carried out by the father of the present ruler. They comprised canals, banks, and roads, and some idea of the extent of the undertaking may be gathered from the fact that in one year the amount of the earthwork reached to nearly seventy million cubic yards. As may be expected in a country in which skilled labor is both scarce and expensive, the use of earthwork instead of masonry or brickwork will, in all cases to which it is applicable, be adopted. It forms not only the cheapest, but, when of good quality and sufficiently plentiful to render the maximum dimensions of no consequence, the best description of material for that particular class of work.

A glance at the physical contours of that portion of Egypt which lies between the mountains of Libya on the west and those of Arabia on the east, will demonstrate in what manner, and the reason why, it became affected by the inundations of the Nile. If two sections be made of this part of the country nearly at right angles with one another, it will be found that one, which may be termed the longitudinal section, has a gradient or slope which is practically identical with that of the river itself during flood time. The other, or cross section, has a gentle fall from the river banks towards the desert, so that when that point is reached the total difference of level amounts to between 13 ft. and 14 ft. The nature of the soil of Egypt renders these periodical inundations indespensable to its permanent fertility. A geological section shows an upper layer of ooze resting upon sand and gravel, which in their turn repose on a bed of clay. The substratum, moreover, is impregnated with various salts, to such a degree that if the land be not overflowed for a few years it becomes so salted as to be perfectly useless for purposes of cultivation, and remains so until it is thoroughly washed by another inundation. In

addition to the duty already marked out for the future irrigations works of Egypt, they have other functions to fulfill. Among these are the construction of banks or walls for the retaining and storing of water, not only to prevent the salting of the land, but also to raise the water so as to enable it to command land situated at a higher level. One of the oldest works of this kind was undertaken to preserve the city of Memphis. It was in the early part of the present century that the great work was commenced of forming throughout the whole of Upper and Middle Egypt a series of basins in which the floods might be successively and thoroughly utilized. In order to complete this project in an effectual and certain manner for the latter part of the country, it will be necessary to construct a canal of great magnitude, already proposed, and the line of which has been determined.

It has been recently proposed by a well-known authority—M. Linant Bey—to restore the ancient lake Mæris, which Herodotus states was an artificial lake formed to store the waters of the inundation, and distribute them as required during a season of drought, or when the floods were insufficient to irrigate the neighboring country. It is not worth while investigating the cause of the destruction of this lake, but we may briefly notice the advantages which would accrue from its re-establishment. It appears that by the formation of the necessary tanks forty-two thousand acres of fertile land would be lost to cultivation; but, on the other hand, by converting this land into water, so to speak, it would be possible to irrigate or bring into cultivation during drought, or seasons of insufficient floods nearly seven hundred thousand acres. Against this increased cultivable area must be set the cost of reconstructing the necessary banks, sluices, channels, and other works. This cost is very much enhanced by the fact that the level of the present bed of the ancient lake is nearly 27 ft. higher than it originally was. M. Linant Bey estimates that nearly thirty million cubic yards of earthwork would be required to construct the works. Provided the result would recoup the outlay, there would be no difficulty either in finding the necessary capital or in carrying out the undertaking.

Coming down to our own times, the public works constructed recently in Egypt are of a character which speaks well for the future prosperity of the country, whether they be regarded as intended to promote the fertility of the soil, the increase of intercommunication, or the interests of commerce. Until the Euphrates Valley Railway is made, Egypt will constitute, as it does now, the shortest route to our Indian possessions and to the East generally—a route very considerably facilitated by the opening of the Suez Canal. Twenty years ago there was no railway across the desert, either from Cairo to Seuz or from Alexandria to Cairo At present there is comparatively a good port at Suez on the Red Sea, while similar accommodation has been provided at Alexandria, and recently very much extended and improved. Both these towns have also been furnished with waterworks. Under the present ruler the railway system has been greatly extended, especially in the Soudan district. Sugar and other manufactories have been established, and no efforts seem to be spared to promote the welfare of a country which is renowned for its antiquity and former magnificence. A point worth adverting to in connection with our subject is whether it will be found advisable in future to resort to other means to irrigate the land than that of simply raising embankments of various heights. It is not improbable that when all the land situated at the lower and consequently more favorable level be brought into cultivation, the aid of machinery may be called in to raise the water to a height sufficient to command the land placed at a greater altitude.

Railway to unite Greece and Turkey.—A concession for the construction of a line to connect the Greek railway lines with the railway system of Turkey has been granted to a M. Piat, an engineer, who has ceded it to M. Singros, a banker of Constantinople. The latter is engaged in treating with the Greek Government. The project of constructing a line from Patras to Athens will probably be revived.

REFRACTORY MATERIALS—ON FIRECLAY AND OTHER REFRACTORY MATERIALS.*

By GEORGE J. SNELUS, F. C. S.

From "Engineering."

It will be admitted by all concerned in the manufacture of iron and steel, that it is of the utmost importance to obtain good materials for building their furnaces, while at the same time it can scarcely be said that our knowledge of refractory materials is in a satisfactory state. With these convictions, the writer ventures to place the little information he has been able to gather upon the subject before the Iron and Steel Institute, with a view of eliciting discussion, in the hopes thereby of increasing the general stock of knowledge.

Although it is generally allowed that the ultimate chemical composition of a brick does not altogether decide its fire-resisting property, yet, it is often possible to judge from a chemical analysis whether a clay will answer for a given purpose or not.

Thus it is found that the presence of alkalies in sensible quantity, say, about 1 per cent., confers so much fusibility upon a clay as to render it unsuitable for very high temperatures. This is well seen in the analyses of clays from the Dowlais and the Newcastle district. The Dowlais clays, numbered 9 and 10, contain respectively 1.43 per cent. and 1.13 per cent. of potash, and though bricks made from these clays are used for forge purposes, yet they will not stand above one month in mill furnaces, whilst bricks from clays 11, 12, 13, and 14, last for three months.

Mr. Pattinson believes that it is chiefly owing to the presence of the rather large proportion of alkalies that the Newcastle bricks are less refractory than the Stourbridge.

Lime and magnesia exercise a fluxing effect when present, but when mixed with silica, as in the Dinas bricks, a small quantity of lime is useful as a binding material, as it can be more intimately combined with the particles of quartz than any other similar substance.

Oxyde of iron also exerts a fluxing effect, though in a less degree. It will be noticed that none of the Stourbridge clays contain over 2 per cent., but if alkalies are absent, iron oxyde may be present, up to about 3 per cent. without affecting the fusibility of the bricks in a very serious degree. This may be seen by a reference to the analyses of the well-known Glenboig bricks, and of the St. Helens' bricks. Blocks from St. Helens last well in the hematite furnaces of West Cumberland. The writer has found these bricks to bear the scouring action of the highly basic slag of a Bessemer furnace better than those from the Leeds district. If, however, the brick is required to stand the intensely high temperature of a steel melting furnace, even this small proportion of oxyde of iron becomes injurious.

Alumina appears to be singular in its action, for while it is well known to be one of the most infusible substances in nature, and the compound Bauxite, and also highly aluminous clays, as for example the Glenboig, and notably that from the large firebrick works in Maryland, are highly refractory, and ordinary clay, containing less alumina, is less fire-resisting, yet when alumina exists in small quantities in silica bricks, it appears to increase their fusibility. This may be seen by reference to the tabulated analysis and remarks attached.

The plasticity of a clay depends on the presence of combined water, and to some extent upon the proportion of alumina. Thus the Glenboig clay, which contains a rather large proportion of alumina, is frequently of such a soapy character that it is used instead of soap for washing the hands. The well-known Porcelain clay or Kaolin, is highly aluminous, and is prized chiefly for its very plastic nature.

These properties cause the clay to shrink much in drying and firing, but after having been highly fired the material then suffers much less change of volume by subsequent changes of temperature. Hence it is that Glenboig

*Paper read before the Iron and Steel Institute at Manchester.

bricks expand and contract so little upon heating and cooling, thus rendering them valuable in situations where changes of form would cause serious inconvenience, as in the regenerators and roofs of Siemens' furnaces.

Silica is also a highly infusible substance, but unlike alumina, its particles have no tendency to adhere or bind together except under the influence of the most intense heat. When, therefore, this material is used for making bricks, a building substance has to be mixed with it. This is the case in the manufacture of the Dinas, or silica bricks, which were formerly made from the Dinas rock, to which a small portion of milk of lime was added. It is now found that these bricks can be made from any pure silicious stone, by grinding it up and mixing about 1 per cent. milk of lime with it.

In the case of the ganisters, now so largely used for lining Bessemer converters, the cementing material is alumina, which is found naturally combined with the silica. But in this case the physical condition of the substance is of great importance, because it is used in the raw state, or at least without undergoing the process of burning. It is, therefore, important, that while it should not shrink much on heating, it should yet bind well together.

The peculiar black ganister of Sheffield possesses these properties in a high degree, and the writer has found none beter than that sent out by Mr. Lowood. The rock itself appears to have been subject either to extreme compression or to heat, as it has a peculiarly close texture. Sheffield has, however, by no means a monopoly of this substance, or at least of materials that answer the purpose, as Dowlais and Ebbw Vale are now both making their own from local sources. Even pure quartz rock can be made to answer, by mixing a proper proportion of aluminous clay with it. Where, however, the natural black ganister can be obtained, nothing can answer better for all purposes.

There is another peculiarity possessed by silica, which is, that bricks made from it expand when burnt, so that in making silica bricks the moulds must be smaller than the brick.

Thus, for a 9-in. brick, the mould would only be about $8\frac{3}{4}$ in. long. Every mixture, like every clay, has its own factor of expansion or contraction for the same amount of burning, and this is either increased or diminished by variation in the intensity of heat applied. The clay from which the St. Helens' bricks are made shrinks considerably during drying and burning. Thus, for a 9 in. by $4\frac{1}{2}$ in. by $2\frac{7}{8}$ in. brick, the mould is $9\frac{5}{8}$ in. by $4\frac{7}{8}$ in. by $3\frac{1}{8}$ in. For Glenboig clay, a shrinkage of one-twelfth is allowed, that is, the mould for a 9-in brick is made $9\frac{3}{4}$ in. long.

Silica bricks not only expand during burning, but do so still more upon being subject to intense heat, contracting again on cooling; and this expansion and contraction is one of the most important points to take into consideration in building steel-melting furnaces. At Dowlais, the man in charge of the furnaces is expected to slacken the tie-rods above the furnace while the heat is getting up, and to tighten them as it goes down, so as to follow the expansion and contraction of the roof. At Crewe, it is attempted to make this self-acting, by the use of volute springs between the brick staves and the nuts on the tie-rods passing through them; while at Creusôt, they try to make the furnace casing so strong (by the use of wrought-iron girders for brick staves, and very strong tie-rods), that the centre of the roof must rise and fall to allow for the expansion and contraction.

Mr. Riley states that, when at Dowlais, he found the quantity of iron made in a puddling furnace was directly as the percentage of silica in the clay used for making the bricks.

Titanic acid has been shown by Mr. Riley to exist in nearly all clays, but it does not appear to influence their fusibility in any marked degree, and it probably plays the part of silica, to which it is closely allied in all its properties. As much as 1 per cent. was found in Stourbridge bricks, but only traces in silica bricks.

It need hardly be pointed out that it is not sufficient to have a good material. Great care must be exercised in manipulating it. If it is to be made into a brick, every pains must be taken to dry it gradually, and to fire it evenly, and to a proper point; while, if it is to be used

in a semi-plastic state, as in the state of ganister, it should be equally moist throughout, so as to dry evenly, and not so wet as to cause it to crack, or so dry as to prevent it binding.

But there is another practical point in the management of firebricks which is too often overlooked. Bricks are very porous bodies, and absorb a great deal of moisture, even when under cover, and, of course, much more if allowed to get wet. In fact, apparently dry bricks often contain a good deal of water, and if put into a furnace in this state, and the heat is got up rapidly, the bricks crack and crumble, to pieces. This is especially the case with silica bricks, and the writer has known instances of bricks being condemned as chemically bad, when the fault lay with those who used them without properly drying them. It is well in the case of silica bricks to actually set them as hot as they can be handled. In all cases when a furnace is first started, and especially with Siemens furnaces, a very small fire should be kept up for several hours and then very gradually increased. This plan will add weeks to the life of these furnaces.

Most blast furnace managers know and practise this very slow and careful drying of their plant, but it is too often neglected in mill and other furnaces.

BUILDING STONES.*

From "The Building News."

The working and application of building stones date back to an early time, and the question of their relative merits, causes of decay, and means of preservation have for some time engaged the attention of scientific men. It is, therefore, no new subject I introduce to your notice, but one which I trust may, on account of its importance, prove of interest; for, next to the design of an edifice, the selection of the materials of which the building is constructed occupies a prominent place. A proper knowledge of the composition and durability of the principal material used in building can, therefore, be hardly overrated. Chemistry, geology and the study of architecture and engineering have each more or less to do with the attainment of a true understanding of the quarrying of stone and its adaptation to building purposes, and I therefore thought the Junior Philosophical Society would deem a discussion on this subject one of no mean interest. Without further preface I would classify stones employed in works of construction under two heads—viz., those suitable for foundations and those adapted for face work. In the former case, if the foundations and lower part of a building be under water, where perhaps a rapid current flows, or in the case of a sea-wall subject to the influence of powerful waves, a heavy quality of stone must be used, since the weight of all bodies when submerged is evidently reduced by the volume of water displaced —for instance, the lightest stone we have, the *Godstone Gatter* or *Reigate*, belonging to the upper greensand formation. This stone, when used on building land, weighs 103 lbs. per foot cube, but supposing the same stone used in sea water the effective weight would be only 37 lbs. to the cubic foot, since it would then be reduced by about 66 lbs., the average weight of a cubic foot of sea water. The top bed of this soft calcareous sandstone is used for scouring purposes, and it is known as hearthstone; the second bed of the quarry is used for road-making and rough-walling, and the third bed is suitable for architectural works, as it will withstand the action of fire, and is hence known as *Fire Stone*. Westminster Abbey was formerly built of it, and architects used it where lightness was necessary. Sandstones are composed either of quartz or silicious grains insoluble in water, cemented by argillaceous, silicious, calcareous, or other matter, generally consisting of about 93 to 98 of silica, with 1 to 2 of carbonate of lime. When of good quality they

* A paper read before the Junior Philosophical Society by A. T. Walmisley.

prove very serviceable, and have been largely employed in the northern and midland counties. The Cragleith and Stancliffe or Darley Dale (Derbyshire) are considered the best specimens of this kind of stone. The former has been used a good deal in the neighborhood of Leith. Many of the public buildings at Edinburgh have been made from it. It is an excellent stone. When the grains composing sandstones increase in dimensions they are designated conglomerate. The dark gray varieties of sandstone from the vicinity of Swansea, the Forest of Dean and Dundee, are heavy enough for water purposes, and weigh about 170 lbs. to the foot cube. The granite of Leicestershire is one of the heaviest stones we have. It is really a syenite, not a granite, as it contains hornblende and no mica, which all true granite possess. A heavy stone is also found in the western islands of Scotland, particularly in the island of Tiree. This metamorphic limestone is composed of carbonate of lime, with a good proportion of hornblende, or rather cocolite, a species of augite, in small nodules. As a rule, limestones are considered better than sandstones, but, in all cases where stone is continually acted on by water, sandstone is preferable to limestone, since it is not so likely to be acted upon by the molluscæa, which frequently bore calcareous stones, converting gradually the smooth face of the stone to a rough face, and leaving interestices for the water to get into and wear away the stone. In the case of a sea-wall entirely above the water at low tide limestone might be employed, as at Tiegnmouth, or above low water mark in the case where the lower part is always under water. In the construction of the Royal Border Bridge over the River Tweed, on the Newcastle and Berwick Railway, some experiments were made on various stones from quarries in the neighborhood, in order to test the resistance they offered to vertical pressure. The specimens selected measured 1 in. square in the cross section and 2 in. long, this being considered a nearer approach to general masonwork than an ordinary simple cube 1 in. in the side. The result gave an average of 195 tons per square foot. The closest grained and finest in texture bore as much as 362 tons per square foot, while the more coarsely gritted specimens, and those which had a more sandy appearance, resisted only a pressure of 67 tons per square foot. It is to be observed that no signs of yielding were apparent until 92 per cent. of the ultimate crushing weight was applied, when a gradual crumbling of grains of sand proved that they were nearly loaded to their maximum power of resistance. In almost all varieties of building, the specific gravity or weight of the stone employed enters into the calculation, as it is of the utmost importance that the amount of pressure produced by an arch, wall, or column, as the case may be, should not be underrated. As a general rule, stones should not be made to carry a weight exceeding from $\frac{1}{8}$ to $\frac{1}{10}$th of the pressure calculated from that which has crushed them in small experimental cubes. In the Royal Border Bridge the weight borne by each square foot of ashlar in the bridge was a little above 2 tons, whence it would be seen that the pressure on the ashlar in that work (in connection with the experiments made) was about $\frac{1}{10}$th of that which would crush the stone. In Gwilt's "Encyclopædia of Architecture," the pressure on the piers at St. Paul's and other remarkable structures is given at 17.7 tons per square foot on the piers of the cupola of St. Paul's, London; 13.6 on the piers of the Hospital of the Invalides, Paris; 26.9 on the piers of the cupola of the Pantheon, Paris; 27.0 on the piers of the cupola of St. Méry; 15.0 on the piers of the cupola of St. Peter's, Rome; 18.1 on the columns of San Paolo Fuori le Mure, Rome. When the base of solid remains the same, height influences their strength. A very thin stone easily fractures. The experiments which have been made with a view to discover the influence which form has on the resistance of stone have shown that the different solids, the bases of which have an equal area, resisted best as their section approached a circle, and that practically the resistance is in the inverse ratio of the perimeters of different figures with an equal area. It is also found that those sandstones which have the highest specific gravity possess the greatest cohesive strength, about the least quantity of water, and disintegrate the least under changes of the weather. It

is important to bear in mind the action of the atmosphere on various specimens of stone, especially in towns, where, in consequence of the air and the rain containing more or less carbonic and sulphurous acids, derived from the vapor of coal in combustion, every kind of building stone is acted upon thereby. This is very noticeable in the case of sandstones, which form a sort of filter, from their susceptibility of imbibing moisture ; but the power of stone to absorb water to a large extent does not prove that it would not stand the frost. A stone may be durable as well as porous. Good stock bricks absorb a large quantity of water, yet few substances are more durable and resist frost better. When the adhesive strength of the particles of any stone is less than the expansive power of water when converted into ice, then common sense tells us the material would be broken by the frost ; but it does not of necessity follow that because a stone takes up a certain amount of water it suffers from frost. Stone for building purposes should possess compactness and durability, that it shall not be affected by any natural agents as the atmosphere, water, heat and frost ; also hardness, or the power of attrition, which enables it to resist blows and strength ; or the power of resistance in every direction. The under beds in some quarries produce harder and denser stones than the upper beds, but are more expensive on account of the time, labor, and cost of blasting and removing. This, however, depends on the position of the quarry. It is almost impossible to lay down any fixed rule as to what stone should, in different situations, be actually employed. The transport of the material, expense of labor, &c., have to be considered as well as the design and external appearance. If possible and suitable, material near at hand is usually adopted, it being generally considered that stone employed in the vicinity of its native quarry withstands the effects of the atmosphere better than when removed further off. It is to be regretted that the large increased demand for building stone has been attended with a decreased care in its selection. Properly, stone should not be too hastily removed from the neighborhood of its quarry. It requires to season quite as much as timber does. There is, as it were, the sweating of the stone, and, after quarrying, it should be allowed to remain for a time in the quarry to harden and allow the quarry water to run out.

Buildings in this climate are found to suffer the greatest amount of decomposition on the southern, western and south-western fronts, generally most exposed to wind and rain. Decomposition is effected both by chemical and mechanical means—the stone applied to buildings being as subject to its action as when attached to native rocks.

Stones for building are either crystalline or stratified, and may be classified under three divisions—Argillaceous, Silicious, and Calcareous ; although the components of some quarries vary very much, stone being simply an aggregation of particles composed of one, two, or more minerals—silica, alumina, lime, and magnesia, combined with acids, water, and other matter. The argillaceous, though used largely in an artificial state—as in the case of bricks—are not suitable for building in the natural state. Where clay is plentiful, brickwork is generally cheaper than stonework ; but if much labor is required, stone can be used equally cheap. Yorkshire flag is the name generally given to sandstone, known as Bramley Fall, and is that most in use for paving and coping where strength and durability are required. It is a millstone grit from the carboniferous formation. The original quarry was situated near Leeds, on the estate of the Earl of Cardigan, but has been worked out for some years. There were six beds, with a total face of 34 ft. The top bed, about 4 ft. thick, was called the rag ; 2nd, 16 ft. thick, and 3rd, 4 ft. thick, both producing good stone ; the 4th, a red stone of inferior quality ; the 5th and 6th, each 3 ft. thick, and of good quality.

Granite is an example of a silicious stone, and one now much used for engineering purposes. Though employed a great deal by the Egyptians, granite was not much used for building purposes in this country until selected by Messrs. Rennie for their bridges over the Thames. Aberdeen granite, of which London bridge is constructed, is considered superior to Cornish granite, of which

Waterloo-bridge is constructed—the former abounding more with quartz, the latter more with felspar, possessing a portion of potash in its composition, which is considered an agent of decay. Gray granite is more generally employed than red, the latter from its excessive hardness being more difficult to work.

The quartz may be considered as pure silex—$Si\ O_2$, chief among minerals, specific gravity, 2.6 will scratch glass.

The analyses of *mica* vary—color varies from gray to black, specific gravity 2.0 to 2.5.

Felspar, grayish white, or flesh-red tint, specific gravity 2.54. The felspar is the first to decompose, next the mica, but the quartz is imperishable. The coloring matter in granite is felspar. Geologists have been much engaged in settling the question whether granite should be classed as Metamorphic and not as a Plutonic rock, but opinions differ on this point. Metamorphic rocks or stratified crystalline rocks are those produced by a species of chemical action resulting in an alteration of form. They are the result of long-continued chemical, physical, and mechanical change, taking place in rock masses by which their appearance and structure becomes quite different to that which they represented at the time of their formation. Plutonic rocks are those igneous rocks which have not overflown surface, but cooled at great depths, and differ from the volcanic rocks, or those which have cooled at or near surface, by their more crystalline texture and by the absence of pores and cellular cavities. Granite is essentially an igneous rock, though it sometimes presents a bedded appearance. Most quarry workers consider it has a bed, but this cannot be true in a geological sense, the term "*bed*" being peculiar to stratified rocks, and meaning the original plane of deposition of sedimentary or stratified rocks. In setting stones of the latter description care must be taken to lay them in their natural or quarry bed, parallel with the horizon. All stone is said to be capable of bearing greater pressure when laid in its quarry bed than in any other position, but with stone formed in strata and laminated it becomes a necessity, unless a stone is enclosed on both sides by other stones laid in their natural bed, when it may be set with its laminæ perpendicular to the horizon, in the case of a vertical pressure, as the side stones prevent the side laminæ buckling out or flaking off through exposure to the atmosphere or frost; but, generally speaking, in all cases the laminæ to be properly set should lie in planes perpendicular to the pressure; and in the case of an arch stone at right angles to the line of thrust. This will appear evident if we consider the laminæ to be represented by the leaves of a book—a pressure on the back of a cover tending to buckle out the pages and a pressure on the side covers tending to bind the pages closer together. We find also that, however tightly books are packed in a bookcase, dust will wear itself in at the top or exposed edges of the pages, and so will air and water wear itself into the exposed cavities, be they comparatively large or minute, on the exposed face of a stone. Stones of a silicious nature are much less liable to decay than limestones, as decomposition generally commences with the destruction of the base. Stones composed of thin layers or plates, as slates, and some sandstones, are not so durable as those in which the texture is uniform, or the grains or concretions small, as granite in which the essential ingredients, felspar, quartz and mica, are scattered irregularly throughout the mass. When, as in the case of sandstone, the base is highly impregnated with silica, it becomes hard and seems to defy composition. As the particles which are held together are not acted on by air or water the quality of the sandstone depends upon the durability of its cementing properties. The disintegration of rocks and the combination of loose particles which rolled off the surface from exposure to the action of the air and water becoming indurated and forming compact rocks lower down, suggested the aggregation of particles by some common cement to form an artificial stone. A paper on building stones would be incomplete without alluding to its use and manufacture.

In the artificial stone, as originally patented by Mr. Frederick Ransome, broken flint suspended in wire baskets within boilers, is subjected to a strong solution of caustic alkali (soda or potash) at a high temperature, say 300° Fahr.,

under a pressure of from 50 lbs. to 80 lbs. per square inch, which in a semi-fluid state act as a medium to form a mass uniformly equal in its composition and texture. The alkali attacking the flint precipitates the earthy and foreign particles, which remain in the bottom of the vessel when the solution is drawn off ; a large proportion of the silica is dissolved, and the solution can then be evaporated, as much as may be deemed necessary, to any required degree of consistency. Taking soda as the alkali, with a silica base, the following proportions—20.43 per cent. of silica, 27.05 per cent. of soda, and 52.52 per cent. water—produce a transparent solution (average specific gravity 1.6), which, on the application of a strong acid, becomes a solid mass by the precipitation of the silica. A little powdered flint is generally added for the purpose of taking up any excess of alkali which might prove injurious. The whole being worked in a pug-mill for about twenty minutes becomes a sort of granulated tenacious substance, like putty, which can be squeezed into moulds in any form required, and is capable of sharp outlines. After leaving the mould the cast is allowed to dry slowly, and then is submitted in a potter's kiln to a gradually increasing temperature, until at the end of about forty-eight hours it attains to a bright red heat, which is maintained for some time, and allowed to cool gradually, occupying altogether about four or five days. During this process the water is entirely driven off, the silicate of soda produces another silica insoluble in water by part of the soda combining with an additional portion of silex at the high temperature to which it is subjected, and the whole forms a compound possessing the appearance and character of natural stone, though harder in texture. Its application depends on the materials employed. When worked up with clean raw materials, such as sand, clay, portions of granite, marble, &c., together with a small portion of powdered flint, it is most suitable for moulding. When coarser descriptions of sand, grit, &c., are employed, grindstones of all kinds can be formed. By increasing the quantity of silica and subjecting it to a greater degree of heat, any amount of hardness can be attained ; indeed the substance of the artificial stone appears to be sand aggregated and held together mechanically by the tenacious quality of the fused silicate of soda, which, during the process of manufacture, becomes intimately combined with the particles. Other varieties of artificial stone are formed with lime, or its carbonate or sulphate, as the base, and in a few instances they consist partly of organic matters combined with inorganic matters as the base. The use of silica, however, as a base supplies a compound superior in strength and durability to these productions, and more capable of resisting both impact and pressure. Sir John Hall some years ago boiled red sand with sea water for a considerable time, subjected to pressure, and obtained a substance nearly as hard as natural sandstone. Another experiment, submitting pounded chalk to heat under pressure, changed it into crystalline marble, and pounded basalt became converted under the same process into greenstone.

In Ransome's process a well-proportioned combination of silica and the alkali forms a kind of insoluble glass in the process of baking, which firmly holds the mass together, and affords protection against air or other fluid injuring the combined particles. Improvements have, since the patent was taken out, been made in the manufacture by the inventor, and the discovery has supplied a great desideratum, though it cannot, in the author's opinion, be said to supersede carved stone ; but, considering the large demand there is for stone to be applied for building within a limited time prescribed by contract, the manufacture of such a material artificially is of the highest value, and capable of extensive employment where good natural stone is difficult to be obtained. It is suitable for all varieties of architectural decorations, and, when made in squares of about 1½ in. thick, for pavements, as in the case of the footpaths on the Albert Bridge over the Thames at Chelsea.

Marble and other limestones belong to the *calcareous*. This type forms the principal ingredient in all cements, and is very plentiful. Numerous statues of antiquity bear testimony to the durability and value of this class. *Limestones* sometimes consist of shelly substances cemented together, when the cement be-

comes affected, first causing unequal decomposition; but they generally consist of pure carbonates of lime and magnesia combined with other matter, and are more or less durable in proportion as they are more or less crystalline. Those employed in building may be divided into three classes—(1), the simple limestone; (2), the oolites, both containing a large proportion of carbonate of lime; and (3), the magnesian limestones or dolomites. The three principal oolites used in this country are the Portland, Bath and Caen. *Portland stone*, a white calcareous oolite or freestone (so-called because easily worked by chisel), due to its being composed of compounds of little spheres. Stone from the Portland quarries in Dorsetshire was formerly common in the metropolis, both for engineering and architectural works. Many of the city churches and public buildings are built of it. It has also been much used for steps, window-sills, copings, strings, and balusters, on account of its moderate hardness; but its use has of late years been much superseded in engineering by granite, and in architecture by other freestones. It was introduced into London at the commencement of the seventeenth century. Inigo Jones used it in the construction of a Corinthian portico to the west front of old St. Paul's; but the stone Sir Christopher Wren used in the construction of the present cathedral was of a superior quality to most of that now brought into the metropolis, as the quarries from which the stones used in buildings erected in the reign of Queen Anne was brought have been long closed, the stone being too hard to work. In the commissioners' report for 1839, they stated in reference to the Portland quarries, "The dirt-bed is full of fossil roots, trunks, and branches of trees, often in the position of their former growth. The top cap is a white, hard, and closely compacted limestone; the skull cap is irregular in texture; it is a well compacted limestone containing cherty nodules. The Roach beds are always incorporated with the freestone beds that invariably lie below them; they are full of cavities formed by the mould of shells, and occasionally contain oyster shells and beds of flint near the top. The top bed is the best stone. It is a free grained oolite, free from shells and hard veins. The bottom bed is similar in appearance to the top bed, and of the same component parts, but the stone is illcemented and will not stand the weather. A middle or curf bed occurs only in the southern-most quarries of the Eastcliff—it is soft to the north and hard to south. The good workable stone in the Eastcliff quarries is generally less in depth than is met with in the same bed in the Westcliff quarries, but the Eastcliff stone is harder, more especially to the south of the island. The bottom part of the top bed in the Westcliff quarries becomes less hard and durable towards the south. The stone in most of the quarries, and sometimes in the same quarry, varies considerably in quality. Such stone as contains flints, or is met with below layers of flints, is inferior and will not stand the weather. The bottom bed in the Westcliff is not a durable stone, but has been worked to a considerable extent, and sold as a good stone in the London market. In every freestone bed the upper part is the most durable and hardest stone. The best stone is in the north-eastern part of the island, the worst in the south-western. The most durable stone has its cementing matter in a solid and half crystalline state; in the least durable stone it is in an earthy and powdery state." Much of this stone, rejected in the building of St. Paul's Cathedral as unsuitable, has since been sold by contract for building. Concrete buildings have of late been tried in some places. While all must admit that a good natural stone building surpasses that of any other material, it may be questioned whether a concrete building, or at any rate one of artificial stone, would not be preferable to a bad natural stone edifice. *Whitbed* is the stone known in London as brown Portland. The so-called best bed or base bed is not the best, although the name would lead you to think so. The Whitbed is rather a darker color than the base bed, but not so fine in texture, and liable to have unsuitable cavities in it, which have to be stopped when the stonework is cleaned down. Among the numerous works built of this bed may be mentioned the new Foreign Office, Holborn Valley Viaduct, and many of the edifices on

the Duke of Westminster's estate. If carefully selected it stands the weather very well, though rather more costly to work. The base bed has been more used in London for external work than it ought to be. It costs less to work and makes a better appearance when first finished, but its use should be confined in London to internal work, or such portions as are not exposed to the weather. The Roach bed, which is found incorporated with the Whitbed and base bed, and is called respectively Whitbed and base bed Roach, is hard, strong, coarse and durable. This latter was used on Portland Breakwater. *Bath stone*, quarried in the county of Wilts, at Box Hill, Corsham Down and Farleigh Down, also in the county of Somerset at Combe Down, belongs to the oolitic series, being almost wholly calcareous, and though comparatively soft when taken out of the quarry afterwards becomes hard and serviceable. It is largely employed for the facings of buildings. Combe Down is quarried on the down from which it takes its name, near Bath. It was used for the restoration of Henry VII.'s Chapel at Westminster, between the years 1808 and 1821, but needs to be selected with great care, the blocks being occasionally subjected to vents which will not stand the effect of the London atmosphere. The major parts of Bath and Bristol are built of it. Corsham Down quarries lie parallel with the Box Tunnel, and produce a stone freer from vents, fine and even in texture. A bed of stone is found below the latter known as Com Grit, a thoroughly strong stone, but too coarse-grained to please the eye. It is largely used for heavy work. Box Ground adjoins the Corsham, and is used for sills, plinths, copings. It is coarse-grained and very durable. *Farleigh Down* resembles the Corsham in texture, but has not been so much used, as the blocks average smaller dimensions. *Caen stone* was brought into London soon after the Norman Conquest, and was extensively employed for inside decoration in the Houses of Parliament, for which purpose on account of its fine even grain and color it is well suited, as it does not require half the labor necessary with Portland stone; but it does not stand well the exposure to the atmosphere of towns, though during the middle ages it was much in demand for buildings in this country. The central tower of Canterbury Cathedral, St. George's Chapel at Windsor, Henry VII.'s Chapel at Westminster were built of it. *Aubigny stone*, quarried near Falaise, near Caen, is very close-grained, and harder to work than the Caen. It is of a colder color, and said to stand the weather better. There are only two workable beds with an intermediate stratum of soft stone. *Ancaster stone*, likewise oolitic, found near the town of that name in Lincoln, was used in the construction of St. Pancras Station and Hotel, but more particularly in its own district. *Doulting and Ham Hill* are both shelly limestones and oolitic, used largely near their own districts in Somersetshire. *Painswick stone*, quarried near Stroud, is also a member of the oolitic formation, close, white-grained, rather finer and harder than the Corsham Down, and consequently more expensive to work. The *freestones of Wardour, Chilmark and Tisbury*, in the county of Wilts, belong to the oolitic formation. The Chilmark is a siliceous limestone, and was employed for Salisbury Cathedral in the thirteenth century, Sir Christopher Wren's report upon this edifice in 1668 speaks of the stone as a little inferior to Portland. At the present day the western front is slightly decomposed, but the rest of the building is in good preservation. Tisbury stone has been used in the restoration of the Chapter House, Westminster. Among the Permian magnesian limestones may be mentioned the Mansfield stone, quarried in the county of Notts. Three distinct varieties exist—the white, red and yellow—the latter from the Mansfield Woodhouse quarry. Owing to their expense they are not much in request, though very suitable for building purposes. The red and white are calciferous sandstones, the yellow a dolomite or magnesian limestone.

The commissioners appointed to investigate the different stone quarries in this country with reference to the selection of the stones for building the new Houses of Parliament, though they admitted that many sandstones as well as limestones possess many advantages in buildings, yet reccommended the magnesian limestone as the most fit and proper material, on account of its more

general homogeneous structure, and the facility and economy of its conversion to building purposes. They selected the magnesian limestone in the neighborhood of Bolsover Moor as suitable for the purpose, being uniform in structure, and containing 51.1 of carbonate of lime, 40.2 of carbonate of magnesia, nearly in equivalent proportions, with the advantageous admixture of about 3.6 of silica.

A cube of 2 in. square was found to require 596.01 cwt. to crush it, and the facility and economy of its conversion to building purposes were also in its favor. Dolomites vary very much. The Museum of Geology in Jermyn Street and the Houses of Parliament were both built of dolomite. The former exhibits no signs of decay, while in the latter it is to be regretted that much of the stone supplied was not taken from the same part of the quarry as that approved of by the commissioners. The former shows that the commissioners could not have selected a better stone, while the latter proves that care is also necessary in its selection from the quarry.

RAILWAY SAFETY APPLIANCES.

By Mr. F. J. BRAMWELL, C. E., F. R. S.

From "Iron."

The total number of deaths to railway passengers from causes beyond their own control for the four years 1870 to 1873, both inclusive, amount to 142, or an average of 35½ per annum, and the accidents which caused these deaths may be divided into seven heads, and more than half—viz., as much as 58.7 per cent. of those accidents—are due to collision, while 12 per cent. are due to the trains being turned into the wrong lines or being "split," and about 9 per cent. are due to trains leaving the rails, another 9 per cent. to defects in the rolling stock, including boiler explosions, fractures of axles and tires, and matters of that kind, and about 4½ per cent. each to accidents arising from trains breaking away on inclines and to miscellaneous causes, while not quite 2 per cent. are due to trains entering stations at too high a speed.

The first of these relate to railway wheel tires. A railway wheel (in Europe) is commonly made with a frame or skeleton either entirely of wrought iron, or occasionally with wrought-iron spokes and rim, but with a cast iron boss, and is tired by a wrought iron or steel tire. With respect to the tire, the common mode of manufacture a few years ago was to make a straight tire bar, then to bend it into a hoop, then to weld the ends of the bar together (and great pains were taken to devise a good form of weld), and then the tire being heated was shrunk upon the wheel. But after all has been done that can be done, a weld is still, it is to be regretted, a matter of uncertainty. Many accidents arose from the fracture of tires at the welds and then the engineer devised a safety appliance. But of late years the engineer has turned his attention to getting rid of the weld altogether, and this he effects by making the tire no longer in the form of a straight bar requiring bending and subsequent welding, but he makes it at once in the form of a hoop in the condition known as a weldless tire. A welded tire is now as rarely to be met with as ten years ago it was unusual to meet with a weldless tire; but although this improvement in the manufacture of the tire itself has done away with the great source of danger (the weld), there still remains the risk of fracturing the solid metal, and therefore the safety-ring is most properly retained even with weldless tires.

Another source of danger in the rolling-stock is the fracture of axles, either those of the engines or of the passenger carriages. These fractures most commonly occur at places where there is a change of dimensions. Railway engineers were among the first to discover

that the providing of adequate size was not sufficient to ensure the durability of axles and of parts subjected to similar strains, and that indeed harm might actually be done by increase of dimensions; for that the neighborhood of a large part to a small one not merely made the smaller section relatively weaker than the larger, but it made it actually weaker than if the larger one were not there; and the railway engineer found that the only way to ensure safety was to prevent abrupt change in form, and having so found he applied this safety precaution.

Under the head of accidents to rolling-stock comes the explosion of locomotive boilers. The explosions of locomotive boilers have a certain peculiarity which demand notice, but time will not permit me to enter upon so wide a subject; to show you, however, the care taken by the engineer to prevent such accidents, I may tell you what is done at the Crewe works of the London and North-Western Railway to insure soundness in their steel boiler plates. In the first place the steel made in large masses by fusion processes, either those of Dr. Siemens or of Mr. Bessemer, is proportioned so that it shall not have more than two-tenths of 1 per cent. of carbon. Such a percentage should, with pure materials give a perfectly homogeneous flexible ductile metal; and to ascertain whether this has been obtained the plates are annealed, and then they must be capable of being bent cold without the slighest sign of fracture; and any piece of the plate must be competent to stand a "punching" test—that is, a hole of five-eighths of an inch diameter being drilled in the plate. A succession of tapered punches are driven in until the hole is enlarged to 1½ inch, or as much as six times its original area, and this without any fracture of the plate whatever. Similarly steel for axles, for tires, and for rails is tested. To such perfection has the manufacture now attained that out of 500 sets of boiler plates of comparatively modern manufacture at Crewe, which have been tested, only one plate has yielded under the test.

In England, happily, we have but few single lines of railway, and collisions arising from the meeting of trains coming in opposite directions are therefore very rare. With respect to those collisions which occur from one train overtaking another, until within the last few years the appliances employed by engineers to prevent this class of accident consisted of a series of signals placed at stations and elsewhere along the line, which were put "On" or to "Danger" as each train passed, remained at "Danger" for a certain time, say five minutes, and then were put to "Caution," remained at "Caution" for a further time—say five minutes—and then were taken off, *i. e.*, were put to "Safety" or "All right." Of late years, looking at the great increase in traffic and at the varying paces at which trains run, such a time system has been considered no longer satisfactory, and the engineer therefore has resorted to the block system, which substitutes the element of distance for the element of time as a measure of safety, and this substitution he is enabled to effect by the aid of the electric telegraph. Occasionally, however, accidents do happen even with the use of the block system. A train has been known to break in half, and the first part of the train having gone past the signal box, the man there has supposed it to be the whole train, and has telegraphed back "Line clear," while in truth the helpless piece of the train was standing on the line. Accidents have arisen in this way, but very rarely, Again, men have made mistakes in their signaling. Sometimes a man has signaled "Line clear," before the train has passed. Occasionally a man who has not received "Line clear," acts as though he had.

Now, I do not suppose the engineer with all his pains will ever be able to entirely render himself independent of the due discharge of his duty by the signalman, nor of the care of others who are engaged in the conduct of the business of railways; but the engineer is always trying to improve his position in this respect, and with this object he has invented an apparatus which shall get rid of the danger arising from one of the two neglects of duty to which I have just alluded, namely, that a man who has not received the "line clear" signal might act as though he had. This particular safety appliance is of the following construction:—When a signal-

man has put his signal to "Danger" it is locked, and that lock the signalman cannot unlock, although he can apply it. It must be undone by apparatus worked electrically from the signal cabin beyond him, and thus, until he has received "Line clear," he cannot again put his signal to "Safety." Efforts are now being made to further diminish the chance of one train overtaking another by enabling electrical communication to be established between any of the signal houses and the driver of a train. This is effected by having isolated surfaces placed at regular intervals along the line with which electrical connection is made by means of a metallic brush attached to the engine, and coming in contact with those surfaces. By this means, although complete electrical communication for the purposes of conversation is not kept up, the directions "Stop" or "Go on" can be given.

Although the question of brakes does not belong particularly to the class of collisions we are now considering, yet brakes have to be discussed in connection with our subject. The improvements that are in use here all operate by applying friction to the wheels, but apply that friction to a large number of the wheels instead of only to a few, and many of the contrivances are made so as to put on the pressure promptly. Although it is probably well to be provided with a maximum power of stopping trains, such a power is not an unmixed advantage. In the first place, although the theory is that the brake shall be so applied as to let the wheels slowly revolve, in practice the wheels are absolutely stopped; they then rub along the rails, flat places are worn in the wheels, and the comfort of traveling is destroyed by the disagreeable jolting of the carriages, a jolting not felt when the brakes are applied to brake-vans and tenders only. Moreover, the rails suffer from the action upon them of these polygonal wheels. Further, in certain cases there can be no doubt that the rapid application of powerful brakes has been the means of destroying life instead of saving it. The greatest possible brake power would be an unalloyed advantage if it were under the control of a man who knew the exact nature of the accident that was happening, and who had ample time to reflect as to the best means of using the power at his command; but as, unhappily, these are not the conditions which commonly attend railway accidents, it is to be feared that large brake power, while most useful in averting collisions, will be in many cases a cause of danger when the accident is one that arises in the train itself.

I now come to the railway safety appliances which have been devised for preventing collisions at junctions; similar appliances are also used for the avoiding of collisions where railways cross one another on a level, and indeed where railways cross common roads on a level, or cross rivers or canals by means of movable bridges.

I now wish to remind you that the railway locomotive is peculiar in respect of the inability of the persons in charge to guide it. They may vary its pace, they may bring it to a dead stop, or may reverse its motion, but they cannot guide it. In this respect their powers compare unfavorably with those of the riders of horses, the drivers of horse-coaches, the drivers of common road locomotives, of traction engines, and of steam road rollers, and with the steersmen of ships; the only persons in charge of a moving machine who were in a similarly helpless condition were those who navigated balloons; but, according to an able article in the last *Quarterly Review*, the balloon is to become "dirigible." But whether balloons are to be really made "dirigible" or not, the locomotive driver will still have to depend upon others for the guidance of his locomotive, and this guidance is commonly effected by means of a pair of moving points, and these points, according to the position in which they are set, either cause the train to preserve its direction along the main line, or force it to diverge down the branch. The points being then the real implements which control the direction of the train, one sees of what paramount importance it is that the positions of these implements should faithfully accord with the signals. In truth, the principal function of these latter is to communicate to the driver through the eye the position of the points; and if this accord be not assured, it is obvious that, although the signals exhibited might not be conflicting among

themselves, their exhibition might lead to most disastrous results.

I come next to safety appliances which are used to prevent the "splitting" of trains at junctions. Force of habit has undoubtedly on more than one occasion caused an unhappy signalman to put his signal to danger to protect a train as soon as ever the engine has passed his box, and has caused him to follow that operation by the pulling of the next lever, whereby he has moved the points and split the train. And to guard against this source of danger some railway companies issued orders that a signal was not to be put to danger until the whole train had gone by; but the risk still remained, and again the engineer was at hand with a safety appliance.

With this it is utterly impossible for a signalman even to unlock the points, but until unlocked they cannot be shifted, and in this manner the danger of splitting a train is for ever at an end. The safety-bar and the locking of facing points have a far higher importance than the mere prevention of the splitting of trains at junctions, because they have done away with the danger of the points not being entirely home, and of their being disturbed by vibration and causes of that kind, and they have therefore made properly constructed facing points safe, to be run through at speed for the main or straight line. This being so, the engineer no longer fears to employ facing-points, and the ability to so use them at will may be made to greatly increase the carrying power of a railway.

I may be, perhaps, accused of representing everything connected with railway management as being in an absolutely satisfactory condition, and as being incapable of beneficial change. Let me say that this is by no means the position I am taking up. I am here, as I told you, to vindicate the engineer, not railway management, and unhappily, from mistaken policy, or from need, or from motives of false economy where need does not exist, the counsels of the engineer are not in all instances allowed to prevail, and thus it is we see certain railways neglecting their duties towards the public by not readily adopting safety appliances. With such neglect accidents ensue; and the public not having the means of discriminating between those companies which do take proper precautions and those which do not, blame the whole railway system and visit also the engineer with censure. This should not be; we should discriminate; and if we did we should acknowledge, I think with thankfulness, the care and pains which are taken by these who adopt all known means of safety to carry on a large traffic without injury to their customers.

LIME IN THE BLAST FURNACE.*

By Mr. I. LOWTHIAN BELL, M. P., F. R. S.

From "Engineering."

In a furnace about 48 ft. in height, the carbonic oxyde generated by the combustion of the coke at the tuyeres, arrives at the throat so speedily that it, with the accompanying gases, leaves the orifice of the structure at a comparatively high temperature. The solid contents filling the furnace, as a consequence, are, within a few feet of the charging plates, in a state of bright incandescence.

When limestone, in its natural state, is used as a flux, it quickly reaches, in such a furnace, a zone where the heat is sufficient to separate the carbonic acid from its calcareous base. The temperature of this region, indeed, is so intense, that not only the carbonic acid associated with the lime, but a portion of that due to the deoxydation and carbon impregnation of the ore, is reduced to the form of carbonic oxyde.

I have shown, on a former occasion, that the smelting of a ton of iron is probably accompanied by the conversion of 6.58 cwt. of carbon from the state of carbonic oxyde to that of carbonic acid. The

* Paper read before the Iron and Steel Institute at Manchester.

carbon in its acidified form in the quantity of limestone consumed, upon one occasion, in a 48 ft. furnace was 1.92 cwt. Hence, we may infer that, were there no reduction of carbonic acid to a lower condition of oxydation, we ought to find, for each ton of iron produced, 8.50 cwt. of carbon, combined with its maximum dose of oxygen.

Instead of this quantity, only 5.47 cwt. of carbon so oxydized was found in the escaping gases of one of the smaller furnaces referred to, per ton of iron of its make.

This change in the composition of the escaping gases of a blast furnace involves more serious consequences than what, perhaps, at first sight might appear.

	cwt. units.
There is the heat absorbed by splitting up carbonic acid containing (8.50−5.47) 3.03 cwt. of carbon	9,696
The decomposition of this carbonic acid carries off the same weight of carbon which it contains, and which escapes combustion at the tuyeres, involving a further loss of	7,272
	16,968
To which has to be added the heat required for expelling the carbonic acid from 16 cwt. of limestone	5,920
	22,888

The coke consumed upon the occasion which furnished these data amounted to 28.92 cwt. per ton of iron, and the heat estimated to be afforded by its combustion, using air heated to 452 deg. C. (846 F.), was 104,012 units. The proportion, therefore, of the total heat generated, which was absorbed by the expulsion of carbonic acid from the limestone, and the decomposition of this compound of oxygen and carbon amounted to 22 per cent. Of this, 16 per cent. is due to the use of limestone, and 6 to the dissociation of the carbonic acid, produced by the reduction and carbon impregnation of the ore.

An expenditure of 16 per cent. of the heating power of the fuel, which is rendered necessary by the presence of one of the constituent parts of our flux, affords *prima facie* a strong reason why we should seek to relieve the furnace of a duty represented by about 4½ cwt. of coke, particularly as half this weight of inexpensive small coal sufficed for the purposes of the lime kiln.

I am not aware that the experience of any iron smelter justifies the belief that any approach to this economy was ever realized by the substitution of lime for limestone. On referring to the Clarence furnace books, I find, when using the same quality of coke in each case, one of the smaller furnaces (48 ft.) gave the following results :

14 Days' make per Furnace tons.	Average No.	Coke per ton cwt.	Mine Yielded, per cent.		cwt.
419	3.34	29.06	41.9	Limestone per ton	14.53
444	2.20	39.64	42.6	Burnt lime "	11.14

Other examples from furnaces of similar dimensions gave the following averages :

14 Days' make per Furnace tons.	Average No.	Coke per ton cwt.	Yield per Mine, per cent.		cwt.
404	2.65	29.31	42.0	Limestone per ton	15.89
451	2.10	27.99	42.6	Burnt lime "	11.46

In the first two cases given, the consumption of fuel is practically the same, but the produce of the ironstone (Cleveland), when smelted with calcined limestone, is somewhat better. Discarding this cause of difference, the sole advantage from the use of lime is the increased make and superior quality of the iron. In the next two examples, an improvement in production and grade of metal is also observable, along with an economy of 1.32 cwts. of coke, part of which is probably due to the better yield from the ironstone (Cleveland), as well as to a somewhat superior quality of coke received at the works, when calcined limestone was being used. In none of these instances, judging by the relative quantities of burnt and raw limestone employed, has one half of its carbonic acid been expelled.

The apparent want of reconciliation between theory and practice in the consumption of fuel, when using the flux raw or calcined, is, in my judgment, in a great measure independent of the imperfect expulsion of carbonic acid from

the latter; and further, I am of opinion that a complete separation of this element would fail to effect in a larger furnace, any appreciable good in respect to the coke required for the process.

Omitting the somewhat questionable economy of fuel exhibited by the figures given above, it is not surprising that a furnace 48 ft. high, and containing 6,000 cubic feet, should, with a make of 200 tons to 210 tons per week, be capable of doing some additional duty when relieved of that portion of its work represented by calcining the limestone. In like manner, where a furnace 80 ft. high, and containing 15,000 cubic feet, only runs 350 tons a week, and is, therefore, compared with the former, far above its work, any such relief as that in question may be regarded as unnecessary.

The objects of this communication are to show that this supposition is substantially correct, and to endeavor to reconcile the apparent difference between theory and practice just referred to.

For the purpose in question, two of the Clarence furnaces, Nos. 9 and 10, having a height of 80 ft., and a capacity of 20,500 cubic feet, were chosen. They were blown in about twelve months ago, and were working under precisely the same conditions. No. 9 was supplied with raw, and the other with calcined limestone, and after a few weeks this order was reversed—No. 10 was put on raw, and No. 9 on calcined.

The consumption of limestone per ton of iron, was almost exactly 11 cwt., which, allowing 5 per cent. of foreign matter, would represent 5.85 cwt. of pure lime, or 6.16 cwt., including impurity, had all the carbonic acid been expelled. By the time, however, that the calcined flux was reduced to 8 cwt., the appearance of the cinder indicated a similarity of composition. This was equivalent, if correct, to an admission that the lime still retained about one-half of its carbonic acid, the truth of which was proved by an analysis of the cinder itself.

Composition of Cinder—using.	Raw Limestone.	Calcined Limestone.
Silica	30.84	30.64
Alumina	25.71	25.45
Lime	30.85	31.17
Magnesia	6.92	7.22
Protoxyde of iron	.23	.06
Protoxyde of manganese	.26	.28
Potash	.28	.30
Soda	1.02	1.20
Phosphoric acid	.34	.44
Sulphide of calcium	4.09	4.52
	100.54	101.28

Parenthetically it may be observed, that no change was effected in removing silicon or sulphur by the substitution of calcined for raw limestone, a sample of No. 3 iron from each giving the following results:

	Using Raw Limestone.	Using Calcined.
Silicon per cent	1.91	1.91
Sulphur per cent	.038	.033

With regard to the main object of the experiment, viz., the consumption of fuel, there was literally not the slightest advantage in the use of the flux from which half of its carbonic acid had been expelled. In each case, the burden of mine (Cleveland), on a given weight of coke, remained unaltered, without any improvement in quality manifesting itself, nor was there any tendency to an increased rate of driving. The make was in each case 61 tons to 62½ tons per 24 hours, the quality averaged about 3.75, and the coke a trifle under 22 cwt. per ton of iron.

Applying the same mode of computation employed at the commencement of this paper, the separation and decomposition of half the carbonic acid in 11 cwts. of limestone, is equal to about 5,550 units per ton of iron, the necessity for which was avoided by the previous calcination of the flux. To this must be added 1,950 units, as the heat which will be evolved by the lime reuniting with carbonic acid in the furnace, which, for the present, we will assume to happen. We have thus 7,500 units of heat at our disposal, which, at the usual condition of oxydation of the gases in an 80 ft. furnace using limestone and driven with air at 485 deg. C. (905 deg. F.) represents about 1.79, say 1¾ cwt. of coke.

I propose to endeavor to explain the cause of the disappearance of these 7,500 units, and the consequent non-effect of their representative 1¾ cwt. of fuel.

In round numbers, calcined Cleveland stone, in an atmosphere of carbonic oxyde, may be considered as commenc-

ing to lose its oxygen gas, or in other words, to suffer reduction when it is heated to a temperature of 200 deg. to 210 deg. C., say, 400 deg. F.

Metallic iron and carbonic acid, with some precipitated carbon, are the products of this action ; but if the temperature is raised from 400 deg. to about 800 deg. F., then the carbonic acid, formed by the reduction of the ore, commences to reoxydize the metallic iron formed at the lower temperature, and this proneness to oxydation by carbonic acid increases rapidly as the temperature is raised. Thus, if a mixture of carbonic oxyde and carbonic acid in equal volumes is passed over calcined Cleveland ore at a bright red heat, the latter cannot be deprived of more than one-third of its oxygen ; and in like manner, if spongy metallic iron be similarly treated, it absorbs from the carbonic acid as much oxygen as remains combined with the metal contained in the ore, *i. e.*, two-thirds of that required to constitute peroxyde of iron.

From the physical laws involved in the facts as just enumerated may be inferred :

1. That there is a point in which carbonic acid will render complete reduction of an oxyde of iron by carbonic oxyde impossible.

2. That this point varies with the temperature, *i. e.*, the reducing power of carbonic oxyde is lessened by the oxydizing power of carbonic acid rising as the temperature increases.

Now, my inquiries on this very important question connected with the action of the blast furnace have led me to infer that the gases from an 80 ft. furnace of say 15,000 cubic feet, and running 350 tons per week, are saturated with oxygen, as far as they can be, when one-third of the carbon they contain is converted into carbonic acid. The temperature of the gases when cold ironstone is used, will average under the supposed conditions about 300 deg. C. (572 deg. Fahr.).

By the use of the flux, calcined as it was in the experiment we are considering, 7,500 units of heat per 20 of iron are practically added to the contents of the furnace, and the presence of this heat at once manifested itself by a rise in the temperature of the escaping gases which corresponds to something like 1,500 of the 7,500 units placed at our disposal.

I would here observe that carbon as well as iron, either metallic or in its lower stages of oxydation, is capable of decomposing carbonic acid, and that its power in this respect is also intensified as the temperature is increased.

If, therefore, where by a change in the composition of the materials, an increase of temperature in the reducing zone follows as a necessary consequence, a larger proportion of the carbon as carbonic oxyde in the gases may arise from one or two causes—either the oxydizing influence of the carbonic acid may be augmented by the change of temperature, and so require the presence of a larger quantity of carbonic oxyde to effect reduction, or the higher temperature may enable the carbon to split up more readily the carbonic acid. Whichever of these two causes is the correct one, the result would be the same, viz., an unburning, as it were, of carbonic acid, which means a large absorption of heat and consequent waste of fuel.

In the case we are considering, this waste of fuel has, of course, been met by the additional heat generated, or not required, as explained, by the use of calcined limestone, the loss on the one side being balanced by the gain on the other.

As a matter of fact, this diminution of carbon existing as carbonic acid in the gases is precisely what I found took place in the furnace when calcined limestone in the experiments already described was employed. The analysis of the gases will require repeating, inasmuch as their ascertained composition accounted for rather more loss than the heat which had been added in the manner described.

There is, however, no reason for delaying the communication of these later trials to the Institute. They extended over a period of six weeks at the two furnaces, and the unmistakable conclusion arrived at was, that the expense of calcining the limestone was unaccompanied by any advantage whatever in the operation.

I may add that the presence of caustic lime is supposed, by virtue of the power it possesses of absorbing carbonic acid, to produce the same effect as if this acid were introduced in the form of carbon-

ate of lime. Now lime, in some form or other, exists in calcined Cleveland ironstone to the extent of from 7 to 8 per cent., and magnesia of from 4 or 5. I was therefore anxious to ascertain whether these earths were able, in any high degree, to absorb carbonic acid in the cooler portions of the furnace, and, in consequence, to carry it down where, by its reaction on carbon, a loss of coke would ensue. I would remark that lime and magnesia possibly exist in the native Cleveland ironstone, chiefly combined with silica or alumina, or both; certain it is that the carbonic acid in the raw stone is only about sufficient to form a carbonate with the protoxyde of iron present.

Whatever may be the form in which lime exists in the ironstone in its natural state, when calcined, a mere trace—under 0.2 per cent.—was washed out of the calcined ore by chloride of ammonium, and of this a portion was probably soda or potash. The ironstone (calcined), the size of mustard seed, was exposed for 25 hours, at ordinary temperatures, to carbonic acid. The original ore contained .85 per cent. of this acid, and at the termination of the experiment it contained 1.22 per cent. A second sample was similarly treated in a tube immersed in a bath of melted zinc, having a temperature of probably 800 deg. to 900 deg. Fahr. The carbonic acid it contained at the end of $2\frac{1}{2}$ hours was .77 per cent., after which no change of weight took place.

These experiments prove that the presence of lime and magnesia, as they are found in calcined Cleveland ironstone, are inert so far as any absorption of carbonic acid is concerned.

Physically it would be possible, by a previous fusion of the ironstone with the flux, to render the lime of the latter incapable of absorbing carbonic acid to any extent, which acid would be expelled by such preliminary treatment. There are, however, practical objections to such a course of procedure. Firstly, in a properly constructed blast furnace, say 80 ft. high, with a capacity of 15,000 to 20,000 cubic feet, we have seen the total expenditure of coke, entailed by the presence of the carbonic acid of the limestone, is only $1\frac{3}{4}$ cwts. There is, therefore, no margin to meet any expense which would accompany the operation referred to. Besides this, the altered mechanical condition of the ironstone makes it much less susceptible to the reducing influences of the gases of the blast furnace.

I obtained the following results from specimens of Cleveland ironstone calcined to various degrees of hardness but broken from the same lump. They were exposed simultaneously in the same piece of apparatus during eight hours to a current of carbonic oxyde, at a temperature of nearly 800 deg. F.:

Specimens of Ironstone.	Loss of original oxygen per cent.	Deposit'd carbon per 100 of iron.
Burnt to brick red	56.1	5.6
Burnt to brown, not fused	65.2	21.5
Burnt to dark purple, very slightly fused	52.6	8.8
Partially fused	30.4	1.5
Fused	23.9	.51

Mill cinder which, in mechanical structure, would closely resemble ironstone fused with limestone, only lost 1.35 per cent. of its oxygen during $3\frac{1}{2}$ hours exposure to a red heat. It contained no deposited carbon.

A specimen of properly calcined Cleveland ironstone, and a specimen of mill cinder were placed together during 48 hours in the escaping gases of a 48 ft. furnace. The former lost 52.3 per cent. of its oxygen and contained 2.42 of deposited carbon per 100 of iron; the latter only lost about 16 per cent. of its oxygen and had .25 of deposited carbon per 100 of iron.

These trials prove conclusively that it is best to use ironstone burnt so as to admit ready access to the reducing gases, and that if this be not attended to, the mine will arrive at a point in the furnace where the carbonic acid resulting from its deoxydation will be split up or unburnt by contact with highly-heated carbon, in the same way as happens when this acid is supplied by the limestone.

New Bridge in Paris.—The works for the new bridge joining the Boulevard St. Germain, with the Ile St. Louis, with an extension to the Quai St. Paul, are being pushed forward; and it is expected that the bridge will be opened at the beginning of next winter.

THEORIES OF VOUSSOIR ARCHES.

By WM. CAIN, A. M., C. E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

SEVERAL years ago the writer had occasion to investigate the conditions of stability of a segmental stone bridge, under every probable method of loading. No book in the English language that he knew of, afforded him the means of locating the curve of pressures for an unsymmetrical load (as *e. g.* an engine and train on one side of the bridge), or of determining which was the true curve of pressures out of the indefinite number that could be drawn within the arch ring.

Dr. Hermann Scheffler's German treatise on the "Theory of Arches" solved the problem.

The writer presented this theory to American readers in the October and November, 1874, numbers of this Magazine, together with an account of numerous experiments with wooden arches, in an article entitled "A Practical Theory of Voussoir Arches." As other theories on this subject are still being published and taught, the engineering public are invited to consider *what is the true theory of voussoir arches?*

Some of the points in controversy may be shown, by contrasting Dr. Scheffler's theory with one that has just appeared in the October, 1875, number of this Magazine, by Prof. A. J. Du Bois, who gives there an "Application of the Graphic Method to the Arch." He states that in order that an arch shall be stable, the line of pressures must "lie within the middle third of the arch," and "that is the true pressure curve which approaches nearest the axis, so that the pressure in the most compressed joint edge is a minimum."

Dr. Scheffler asserts that a line of pressures may pass, and generally does pass, outside the middle third of the arch ring and yet the arch be perfectly stable; also that the actual line of pressures in any arch is the one consistent with the minimum horizontal thrust. As a theoretical proof of this last, where vertical external forces alone are considered, we say that the sum of the vertical components equals the weight of the arch, but that the horizontal thrust, which is constant throughout the arch ring, is the minimum that can obtain consistent with stability, for there is no need for a further increase of the horizontal force after it has caused stability. To assert the contrary, would be equivalent to saying, that nature was extravagant with her forces. Why should she, after calling forth sufficient horizontal resistance to insure stability, prodigally increase these molecular stresses? Where would be the limit to this increase? The Rev. Canon Mosely is the author of the "*Principle of least Resistance*," or "*Nature's Economy of Force*," and it inevitably leads us to Dr. Scheffler's conclusions; enabling us to locate the only true and actual curve of pressures in a very simple and direct manner. Numberless illustrations are given in the article before mentioned by the writer, and need not be repeated here. "The true pressure curve" is never by this rule found to be that which approaches nearest the axis; all experiments are against such an assumption.

As to the usual statement, that a line of pressures cannot pass outside the middle third of the arch ring, without the arch tumbling (a fallacy of Rankine and other authors), we have only to remark that experiment undoubtedly and finally disproves it. The conditions of stability for solid and voussoir arches are not necessarily identical. See every experiment recorded in the former article by the writer, in which he says in concluding his remarks upon the experiments: "In every case of *stability* of the arches previously given, it is *impossible* to draw a line of pressures everywhere contained within the inner third of the arch ring. In fact, if such were attempted, it would be found in every case, that such a line of pressures would pass outside the base of the piers or of the arch if used alone." If the reader will construct the line of pressures for any of the experimental arches given by Mr. Bland in his "Experimental Essays of the Principles of Construction in

Arches, Piers, Buttresses, &c.," he will probably reach the same conclusion.

A theory to be of any service to a practical man must agree with experiment. The chemist and physicist found their theories on facts, and revise them in accordance with the latest experiments. The engineer, strange to say, is not so fond of experimenting, but prefers to *assume* a hypothesis and compute the deduction.

This easily accounts for many false theories; as *e. g.*, *supposing* half the weight of two inclined rafters to be acting at their junction; *assuming*, where a beam leans against a wall that the force there is horizontal; *assuming* that the true line of pressures in an arch approaches nearest the axis, or is otherwise than as determined by the principle of the least resistance, or finally in *assuming* that if a line of pressures pass outside the middle third of the arch ring, there as in a solid arch tensile resistances are needed, which, not being supplied by the voussoir arch, insures its destruction. The experiments made by the writer and others go to disprove positively these hypotheses.

Again, many writers divide the *arch* and spandrel into slices by vertical lines of division to get the partial weights and thrusts. As the beds of the ring stones are inclined, except at the crown, this is evidently an incorrect way of procedure. The weight of any number of ring stones with their superincumbent load acting at the centre of gravity, must be combined with the horizontal thrust to get the resultant on the *inclined* bed joint of the lowest voussoir; not on any supposed vertical joint. In flat arches this error may be small; in full centre arches it is appreciable.

There are usually given by writers empirical formulæ for the depth of arch stones at the crown. With a theory that gives quick and accurate results for uniform or eccentric loads, we should, assuming a depth at crown as given by practice, draw lines of pressure for every variety of loading that is usual and see whether the depth is sufficiently great; assuming that the lines of pressure must not pass nearer the edges than a certain distance, which depends upon the compressibility of the material used. A series of experiments with stone voussoirs is probably the only way in which we can hope to arrive at the exact position of these limiting curves; though existing arches would lead us to infer that these curves are not over one-fifth the depth of the joint from the edge; still, as bridges are subject to shocks, it would seem that one-fourth or one-third depth of joint could be assumed with safety.

There is scarcely any subject about which so many different theories have been from time to time advanced as this one of arches. If experiment is to be the criterion, which theory best stands the test?

COUPLED LOCOMOTIVES.

From "The Engineer."

A WIDE diversity of opinion still exists among locomotive superintendents as to the relative merits of coupled and single locomotives. Keen discussions on the subject were carried on years ago in our pages; and it would not be difficult to find a score of combatants ready to enter the lists again and fight over this subject. A very eminent locomotive builder was once shown a very strange looking engine which he was told did very good work. He said he was not surprised to hear it, for "anything would do for a locomotive." The statement was, of course, exaggerated; it was meant as a somewhat bitter jest, and yet it was not wholly untrue. As a matter of fact the locomotive appears to possess an astounding power of adapting itself to circumstances; and so long as good material and workmanship are present, the design of an engine appears to exert very little influence on either its economy or utility. We hear it stated, of course, now and then that only engines of a certain design can do a particular work, but such

assertions must always be taken with a grain of salt. Heavy goods engines with small drivers have ere now been beaten on their own ground by express passenger engines which have hauled as great a load at higher speed and with no excessive consumption of fuel; and goods engines, on the other hand, have before now in the hands of enterprising drivers been on an emergency made to keep perfect time with express trains. It is no doubt to this wonderful power of adapting itself to circumstances possessed by the locomotive that we must look for an explanation of the fact that so many points of apparently vital importance connected with its design and construction still remain entirely unsettled, and ready at any moment to supply matter for a warm dispute between railway men.

As regards the question concerning which this article is written, it may be stated that little has been done of late years to take it out of the region of discussion based on pure theory. While on some lines the coupled engine grows in favor, on others the tendency is to revert to the single engine. There is scarcely a line in Great Britain in which coupled passenger engines are not used more or less. But it has been found in certain cases that single engines can be made to take the place of the coupled engines used for years in conducting a given traffic, and with advantage. There is really no inconsistency in this; it is well known that single engines always run more freely and with less internal resistance, if we may use the words, than coupled engines. On one great line we are assured that the saving in fuel effected by using single instead of coupled engines amounts to approximately 3 lb. of coal per mile, or to something like 10 per cent. of the entire passenger engine coal bill. If this be the case it is not wonderful that single engines have been substituted with advantage for coupled engines. How it is possible to make the substitution is easily explained. The solution of the problem lies in the fact that, with steel rails and a strong road it is possible to load a single pair of wheels sufficiently to secure ample adhesion, so long as the diameter of the wheel does not get below 6 ft. 6 in., and the cylinders do not exceed 17 by 24. Steel rails have enabled us to carry as much as 16 tons with a single pair of drivers; and a very simple calculation will show that in the case of such an engine as we have named an averaged pressure of at least 60 lb. on the square inch throughout the whole stroke would be required to make the wheels slip if the adhesion was but one-sixth of the insistant weight. It may be argued that one-sixth is not enough. The answer lies in the fact that it is found to suffice, and a great many locomotives are now running most successfuly which ought to slip their wheels whenever the average effective cylinder pressure exceeds 60 lb. on the square inch, and we are led to the conclusion either that the pressure does not exceed this, or that the coefficient of adhesion is much greater than one-sixth, for the engines never slip enough to prevent them from keeping time with very heavy trains. It is worth considering again whether coupling an engine confers all the benefits usually supposed to result from the practice. When rails are really in bad condition four wheels seem to possess no more adhesion than two, and we are disposed to regard the coupling of passenger engines, properly so called, as of very little real advantage. The conditions under which coupling is and is not necessary may be very easily defined. When the diameter of the driving wheels, the load on them, the capacities of the cylinders, and the boiler power, are properly proportioned to each other, a single pair of drivers will give all the adhesion requisite for even heavy passenger traffic in ordinary weather. The coupling of such an engine would give her a trifling advantage in bad weather—probably an advantage not worth the extra consumption of coal entailed by coupling. This proposition will not apply generally to engines with driving wheels less than 6 ft. 6 in. diameter.

When a less diameter than this is used, it will be found that with loads of less than 16 tons on a single pair of drivers, the engine will not have adhesion enough in any weather, unless the cylinders are too small and the boiler pressure too low, and such an engine should be four-coupled. When we get to driving wheels at and below 5 ft. in diameter, with 17 in. cylinders, or there-

abouts, then the engine should be coupled all round.

If these propositions are accepted as being approximately accurate, then no difficulty will be met with in deciding whether an engine ought or ought not to be coupled. A given diameter of cylinder may be taken always—within reasonable limits—to represent a given weight of engine, available for adhesion; we may therefore dismiss, in practice, the size of the cylinder altogether, and decide whether an engine should or should not be coupled by the diameter of the driving wheels. Experience then goes to show that wheels over 6 ft. 6 in. in diameter need never be coupled, while wheels under 5 ft. 6 in. diameter should always be coupled; between 5 ft. 6 in. and 6 ft. 6 in. will exist a species of debatable land. It will depend on various circumstances whether it will be best to couple or not wheels of 5 ft. 9 in., 6 ft., or 6 ft. 3 in. If the road is good and tolerably level, and the climate dry, then coupling may better be dispensed with; if, on the contrary, the road is bad and yielding, so that the rail does not stand well up to the driving wheel, but by deflecting tends to permit a redistribution of the load, the leading and trailing wheels taking more than their due weight, and the climate wet, then coupling may be resorted to with advantage. It must be understood that we have been considering the case only of engines making fairly long runs, and that we do not refer at all to such exceptional traffic as that of our metropolitan railways. In main line work it is not necessary to get a train away quickly, and a judicious driver, with the aid of a little sand, will easily get his train into motion without slipping whether his wheels are coupled or not, always provided that they are not so small that they ought to be coupled.

We are quite aware of the fact that exception may easily be taken to what we have advanced, but we believe, nevertheless, that it is in the main consistent with the best modern practice. An idea has been floating about for some time that the coupling question ought to be settled by the diameters of the driving wheels of a locomotive, and all that we have endeavored to do is to put this idea into something like a tangible shape. It may be argued that it is rash to use the diameter of a wheel as a standard by which to settle such a question, because engines exist with wheels much less than the minimum diameter we have named which do not require to be coupled. The answer is that they do not need it because they have small cylinder capacity in proportion to the size of the wheels. They are, in a word, little engines; but such locomotives are not used for working main line traffic, and it is to such traffic and such only that we have referred. The use of steel rails, we may in conclusion point out, has certainly reduced the necessity for coupling, by enabling locomotive superintendents to put loads on their driving wheel, at which an older school of engineers would stand aghast. Whether in the long run it is better, for the interests of share-holders, to use single drivers carrying these enormous loads, or coupled engines carrying much less, we shall not pretend to decide, because questions concerning the expense of maintaining the road are involved, with which just at the moment we have nothing to do. We believe that a single engine properly proportioned will do her work perfectly, and with less coal and repairs than a coupled engine on the same job, so long as the work is not too much for a 6 ft. 6 in. wheel. Whether it is or is not judicious to attempt to run fast passenger and express traffic with a wheel much smaller than this is a matter on which there is very little difference of opinion. We venture to think that the great majority of locomotive superintendents in Great Britain will hold with us that a much smaller wheel than this is not suitable for engines which have to make an average time of forty-five miles an hour, or thereabouts.

The United States Treasury Department has just decided—says the *American Manufacturer*—that the materials of boiler bottom, composed of iron, tin and lead, similar to the terne plate of commerce, loses its identity as terne plate when moulded into shape for use, and is dutiable at thirty-five per cent. *ad valorem*.

THE CONSTRUCTION OF ELLIPSES.

By JOHN H. GILL, C. E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

In all "pocket books," manuals, and instructions on Geometrical Drawing, the Ellipse fares badly, and its beautiful curve is usually degraded to the oval, a combination of circular arcs, or is made to depend upon a string.

By your leave I will give some simple directions for finding any number of points in a given ellipse, without the use of analytical formulæ, and by which any ellipse between its extremes—a right line and a circle—may be accurately drawn, or any *part* thereof, independently of the other parts

First, however, I will describe, by a rough drawing, a simple machine I have contrived for drawing ellipses. It consists of a frame A, A′ (Fig. 1), and the

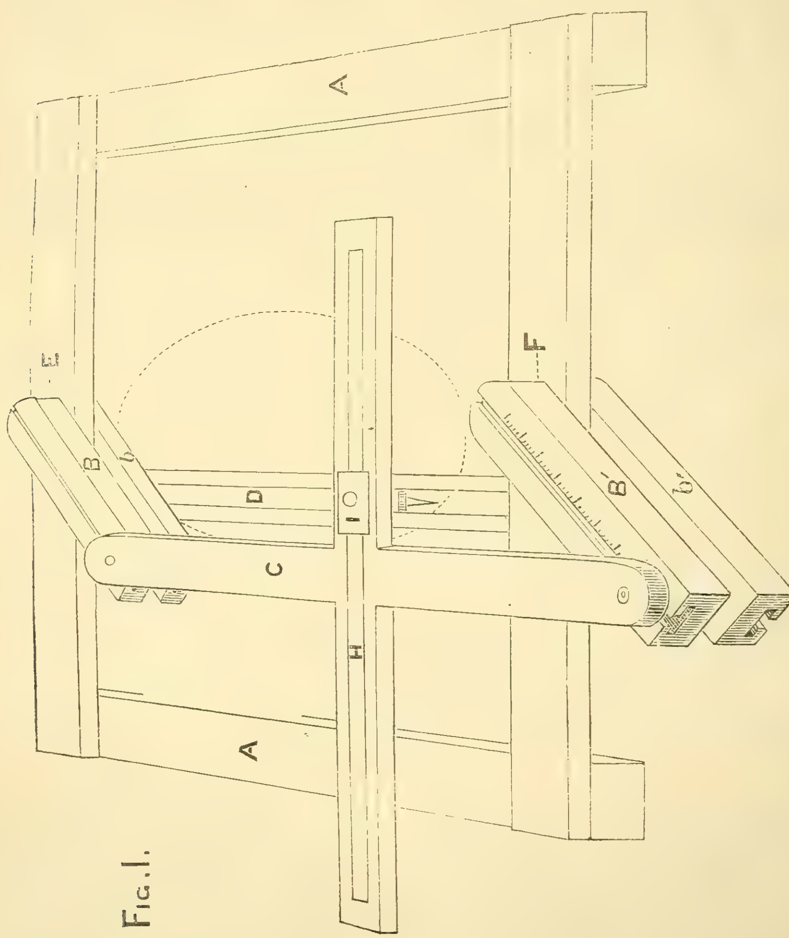


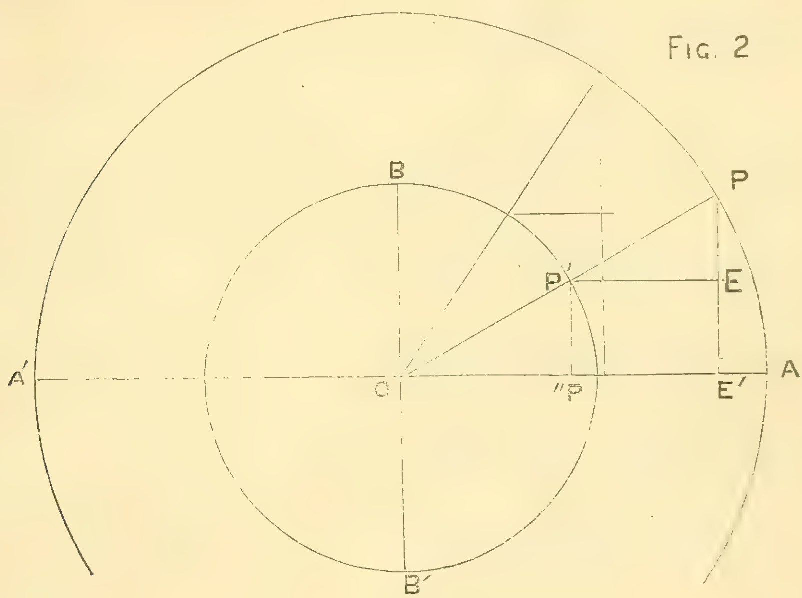
FIG. I.

two pairs of cranks B b and B′ b', having grooves in them as shown, in which work sliding wristpins, which may be secured at any point on the cranks cor-

responding, in distance from their centers, to the semi-major, and semi-minor axes of the required ellipse. Upon these wristpins work the connecting bars C and D, and these are of such length (E F) as to secure a perfect parallelism between the two sets of cranks. C has a slotted bar, H, at right angles to C at its middle point, and D is slotted in the direction of its length. A cross-shaped pencil holder I, slides in both these slots simultaneously. To use the machine, the wristpins of C are set on the cranks B, B′ (by a scale marked on them) at a distance from their centers equal to the semi-major axis of the proposed ellipse, and those of D are set on b, b' at a distance equal to its semi-minor axis. A pencil being placed in the holder, and gently pressed down by a spring or elastic cord; the instrument set over a sheet of paper, and a revolution given the cranks, traces an accurate ellipse. The ratio of the axes may be made anything from unity to infinity. In the first case the wristpins of C and D would be at equal distances from the crank centers, and the resulting curve would be a circle. In the second case one pair of wristpins would be *at* the crank centers, and a right line would be the result. So much for the mechanical method which requires no demonstration, though the following method of geometrical construction, of which the mechanical is an outgrowth, will demonstrate it.

Draw through the proposed center, O, (Fig. 2) of the ellipse two lines perpen-

FIG. 2



dicular to each other. Set off A A′ equal to the major axis, and B B′ equal to the minor axis, and upon them as diameters describe the circles shown. Take *any* point P, on the outer circle, and draw the radius P O, cutting the smaller circle in P′. Through P draw a line parallel to B B′, and through P′ draw a line parallel to A A′. The point of intersection, E, of these lines is a point of the ellipse. For P E : P′ P″ (or E E′) : : P O : P′ O, which expresses the relation between the ordinate of an ellipse, and the corresponding ordinate of the circle described on its major axis. Therefore (Davis Am. Geom. Ellipse, Prop. IV.) E is a point in the required ellipse. In the same manner any number of points may be found.

Table for constructing any ellipse or circle, or parts thereof, whether the centers or foci are upon the paper or not :

(*See Table following page.*)

Example of use of Table.—Suppose it is required to construct an ellipse whose

	1		2		3		4		5		6		7		8		9	
	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y
5°	.996	.087	1.992	.174	2.988	.261	3.984	.348	4.980	.435	5.976	.522	6.972	.609	7.968	.696	8.964	.783
10°	.984	.173	1.968	.346	2.952	.519	3.936	.692	4.920	.865	5.904	1.038	6.888	1.211	7.872	1.384	8.856	1.557
15°	.965	.258	1.930	.516	2.895	.774	3.860	1.032	4.825	1.290	5.790	1.548	6.755	1.806	7.720	2.064	8.685	2.322
20°	.939	.342	1.878	.684	2.817	1.026	3.756	1.368	4.695	1.710	5.634	2.052	6.573	2.394	7.512	2.736	8.451	3.078
25°	.906	.422	1.812	.844	2.718	1.266	3.624	1.688	4.530	2.110	5.436	2.532	6.342	2.954	7.248	3.376	8.154	3.798
30°	.866	.500	1.732	1.000	2.598	1.500	3.464	2.000	4.330	2.500	5.196	3.000	6.062	3.500	6.928	4.000	7.794	4.500
35°	.819	.573	1.638	1.146	2.657	1.719	3.276	2.292	4.095	2.865	4.914	3.438	5.733	4.011	6.552	4.584	7.371	5.157
40°	.766	.642	1.532	1.284	2.298	1.926	3.064	2.568	3.830	3.210	4.596	3.852	5.362	4.494	6.128	5.136	6.894	5.778
45°	.707	.707	1.414	1.414	2.121	2.121	2.828	2.828	3.535	3.535	4.242	4.242	4.949	4.949	5.656	5.656	6.363	6.363
50°	.642	.766	1.284	1.532	1.926	2.298	2.568	3.064	3.210	3.830	3.852	4.596	4.494	5.362	5.136	6.128	5.778	6.894
55°	.573	.819	1.146	1.638	1.719	2.457	2.292	3.276	2.865	4.095	3.438	4.914	4.011	5.733	4.584	6.552	5.157	7.371
60°	.500	.866	1.000	1.732	1.500	2.598	2.000	3.464	2.500	4.330	3.000	5.196	3.500	6.062	4.000	6.928	4.500	7.794
65°	.422	.906	.844	1.812	1.266	2.718	1.688	3.624	2.110	4.530	2.532	5.436	2.945	6.342	3.376	7.248	3.798	8.154
70°	.342	.939	.684	1.878	1.026	2.817	1.368	3.756	1.710	4.695	2.052	5.634	2.394	6.573	2.736	7.512	2.078	8.451
75°	.258	.965	.516	1.930	.774	2.895	1.032	3.860	1.290	4.825	1.548	5.790	1.806	6.755	2.064	7.720	2.322	8.685
80°	.173	.984	.346	1.968	.519	2.952	.692	3.936	.865	4.920	1.038	5.904	1.211	6.888	1.384	7.872	1.557	8.856
85°	.087	.996	.174	1.992	.261	2.988	.348	3.984	.435	4.980	.522	5.976	.609	6.972	.696	7.968	.783	8.964
90°	.000	1.000	.000	2.000	.000	3.000	.000	4.000	.000	5.000	.000	6.000	.000	7.000	.000	8.000	.000	9.000

major axis is 48, and minor axis 12. The semi-axes are 24 and 6.

Under 2 and x are found the abscissas
1.992, 1.968, 1.930, 1.878, &c.

Multiplied by 10, we have for 20,
19.92, 19.68, 19.30, 18.78, &c.

Under 4 and x we have
3.984, 3.936, 3.860, 3.756

Giving for 24,
23.904, 23.616, 23,160, 22.536

which are set off (Fig. 3) on a line rep-

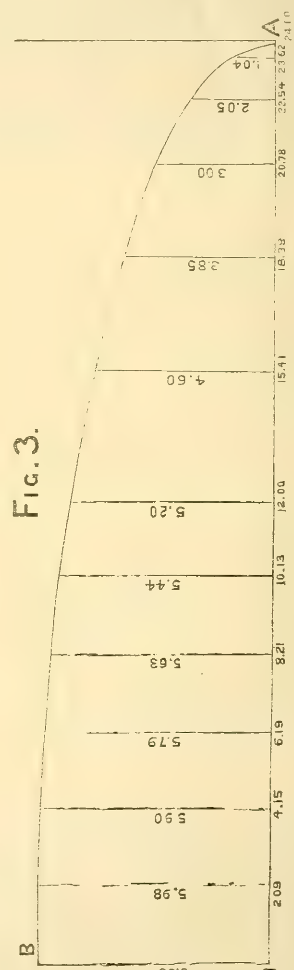


Fig. 3.

resenting the major axis, from a point representing the center of the ellipse; or, if this point is not on the paper, their complements with respect to 24 may be taken, and these distances set off in a contrary direction, from the *vertex* of the

ellipse; at the points so found erect perpendiculars. Next under 6 and under y we find .522, 1.038, 1.548, 2.052, &c., as ordinates, and these are to be set off on the corresponding perpendiculars, and will give points of the ellipse.

For circles the table is used in the same way, the axis being equal the values of x and y will be found in adjacent columns under the same bracket.

The first column on the right gives the angle which the radius to the point, represented by the coordinates on that line, makes with the major axis.

ON THE ALLEGED EXPANSION IN VOLUME OF VARIOUS SUBSTANCES IN PASSING BY REFRIGERATION FROM THE STATE OF LIQUID FUSION TO THAT OF SOLIDIFICATION.

By ROBERT MALLET, F. R. S., &c.

Proceedings of the Royal Society.

The fact that water expands in becoming ice, and that the latter thus floats upon the water, can scarcely have escaped the observation or inference of the acute intellects of a remote antiquity. Its conditions, when more carefully examined in modern times, pointed out the strange and, as it has been called, anomalous fact that water can be cooled 7° or 8° below its freezing-point without becoming solid, and that between its maximum density at about 39° Fahr. and its freezing-point at 32° Fahr., or within the narrow range of 7° Fahr., it expands in the large ratio of 915 : 1000

Standing thus alone amongst observed phenomena in nature, it seems to have suggested to many experimenters the question whether other bodies when liquefied by heat might not also expand when becoming solid by refrigeration. I have not attempted to trace with minuteness the history of past inquiry upon this subject, many loose uncertain statements as to which have for at least a century continued to perplex scientific literature. Réaumur appears to have been the first who gave currency to the statement that cast iron, bismuth, and antimony all expand in consolidating. The like fact has been alleged or left to be inferred with respect to the following substances by the authorities named :

Silver, Persoz.
Copper, Karsten.
Mercury and Gold, as inferred by Nasmyth and Carpenter.
Iron and Furnace-slags, by experiment of Heunter and Snelus, as quoted by Nasmyth and Carpenter.

But of this list the only body, in addition to water, that really appears proved to expand in consolidating is bismuth ; and even this the author cannot affirm upon the basis of his own experiments, but accepts the fact, at least provisionally, as true upon the uncontradicted statements of many chemical authors, and upon the positive assurance which he is permitted to mention by Dr. John Tyndall that he is satisfied of its truth. With respect to all the others, it is the object of this communication to show that the evidence in support of the alleged fact of expansion by refrigeration is illusory and insufficient, and to offer with respect to cast iron, and also with respect to iron furnace-slags, experimental proof of the untruth of the statement.

Certain connected but only collateral facts, having regard to so-called anomalous changes of volume due to temperature, will not be referred to here—such, for example, as the anomalous expansion of Rose's fusible metal, which expands progressively, like other bodies, till it attains the temperature of 111° ; it then contracts rapidly by added heat to 150°, when it is densest (Graham's 'Elements,' vol. i., and Gmelin's 'Handbook'), the circumstances being here probably due to the successive segregation in the mass of alloys differing from each other in

constitution, dilatability, and fusing-points. Or, again, the facts observed with respect to the expansion or contraction in volume shown by certain salts when crystallizing from their solutions, the whole of the conditions as to which have not been as yet made quite clear. The statement that antimony expands in consolidating, as made by Réaumur, has been negatived by Marx. The like statement with respect to silver and copper appears to rest on no better foundation than the observation as stated by Persoz, "that pieces of solid silver float, upon the melted metal, showing that silver expands in sodidifying like water." As to gold, there appears no authority whatever for its expansion on consolidation. Mr. Nasmyth has included it in his catalogue merely on the vague inference that, like silver and copper, it "exhibits surface-converging currents in the melting-pot like those depicted by him for molten iron," which, as we shall see further on, affords no grounds for conclusion on the matter. Reaumur's statement with respect to cast iron appears to have rested upon nothing more than the fact that he had observed certain pieces of cold cast iron to float upon cast iron while in fusion. Until lately this subject generally attracted but little attention, for it had very few, and these mere technical, applications; and to the higher physicist they presented but little interest, because the loosely stated facts, even if accredited, did not in the slightest degree tend to elucidate or explain the remarkable and perhaps still isolated facts as to water and ice. Accordingly, with little or no examination, the statements given for facts by the older authorities have been accepted and become current from book to book of authors up to the present day, as when Dr. T. Thompson says of cast iron that "it contracts considerably when it comes into fusion," or that of Kerl, that cast "iron occupies a smaller space after cooling than when in the liquid state; it contracts in such a manner that, at the commencement of its solidification, it first expands so as to be able to fill up the smallest depressions and cavities of a mould, but after solidifying it contracts"—a loosely worded statement, which in various forms may be found in a great number of authors upon metallurgy and technology. So likewise the statement often repeated, that the value of antimony in type-metal consists in its causing the latter to expand upon consolidation and so perfectly fill the matrix, is presented, so far as the author's reading goes, without the slightest experimental proof of its truth, and appears to rest simply upon Réaumur's statement with respect to antimony itself, which, as already mentioned, has been controverted by Marx. This subject, however, has now assumed greater importance, since it has recently been made by Messrs. Nasmyth and Carpenter the foundation upon which they rest their theory of lunar volcanic action, as presented to us by the surface of our satellite; and the object of the present communication is to show that, as regards the two most pertinent of the substances adduced by these authors, viz. cast iron and iron furnace-slag, the facts entirely fail in support of their theory.

First, then, as to cast iron. It is not a fact that all cast iron in the solid state will float upon all cast iron in liquid fusion, though such might be inferred from the broad and loose statements of authors. Even in the limited form in which the statement is made by Nasmyth and Carpenter—viz. "that when a mass of solid cast iron is dropped into a pot of molten iron of identical quality the solid is found to float persistently upon the molten metal, so persistently that when it is intentionally thrust to the bottom of the pot it rises again the moment the submerging agency is withdrawn" ('The Moon,' p. 21)—is not quite exact.

It is a fact that certain pieces of cast iron in the solid and cold state will float on certain descriptions of cast iron in liquid fusion; but whether the solid pieces shall float or not float in any given case is dependent at least upon the following conditions, and probably upon others not yet ascertained:

1st. Upon the relative specific gravities of the solid and of the fused cast iron both referred to the temperature of the atmosphere. Under the commercial name of cast iron is comprehended a wide range of compounds of iron with other substances, which compounds differ greatly in their physical as well as

their chemical qualities, and have a range of specific gravity of from nearly 7.7700 for the whitest, most rigid, and dense, down to little more than 6.300 for those which are darkest, softest, and most porous. The total dilatation at the fusing-point of the denser cast irons is known to be somewhat greater than that of the less dense; but as the increase in volume may not be sufficient to equalize the specific gravity of a very dense iron when in fusion with that of a very light iron when cold, so it is obvious that a piece of cold cast iron might be so selected in reference to its specific gravity, as referred to that of another sort of cast iron in fusion, that the former should either sink or swim upon the latter by mere buoyancy, were that free to act alone.

2d. Assuming the cold and the molten cast iron originally identical in qualities, whether a piece of the former shall float or not float upon the latter depends not only upon buoyancy as above, but also upon the form of the piece of cold metal—that is to say, on the relation, all other things being the same, that subsists between its volume and its surface.

3d. The force, whatever be its nature, which keeps the piece of cold cast iron floating is of sufficient energy to overcome a considerable want of buoyancy in the cold iron under certain conditions, so that it may float upon molten cast iron whose specific gravity, as such, is much less than that of the colder iron which floats upon it. Messrs. Nasmyth and Carpenter assume, without any sufficient proof, that solid cast iron floats on liquid iron of the same quality in virtue of buoyancy alone, and proceed to state that "inevitable inference from this is that in the case of cast iron the solid is specifically lighter than the molten, and therefore that, in passing from the molten to the solid condition, this substance undergoes expansion in bulk" ('The Moon," pp. 20, 21).

I proceed to prove that this view is altogether contrary to fact. The determination of the specific gravity of cast iron in its molten condition is a problem of considerable difficulty, and can only be solved by indirect means; we cannot ascertain its specific gravity by any of the methods ordinarily employed, nor can any areometric method be used, as any hydrometer or solid of known specific gravity at common temperatures, when dipped into liquid cast iron, changes its volume as well as gets incrusted with adherent cast iron or its oxydes, &c. By an indirect method, and by operating upon a sufficiently large scale to eliminate certain sources of error, the specific gravity of molten cast iron may, however, be approximately ascertained with considerable accuracy. The method adopted by the author was as follows:—A conical vessel, was formed of wrought-iron plate by welding up only, the walls of the vessel being about $\frac{1}{2}$ in. in thickness. It was perfectly smooth in the inside, and the plane of the lip of the open neck was carefully made parallel to the plane of the base. This vessel weighed, when empty, 184.75 lbs. avoirdupois. The orifice of the neck being levelled as the vessel stood upon the platform of the weighing-apparatus, it was filled up to the exact level of the neck with water at a temperature of 60°.5 Fahr., and again weighed. Deducting the weight of the empty vessel, the weight of its contents of water was found to be 94.15 lbs. avoirdupois. From the known volume and weight of the imperial gallon of distilled water, the capacity of the vessel was therefore at 60° Fahr. = 2605.5 cubic inches. As a check upon the results, both as to weight and capacity, the water was measured into the vessel from accurate glass standards of volume. The water employed was that from the well at Messrs. Maudslay, Sons, and Field's Engine Works, Lambeth, where these experiments were conducted, and to whose liberality the author owes the means of having performed them. The specific gravity of this well-water did not very materially exceed that of distilled water, being about 1.0004; but if we apply the necessary correction, the weight of the contents of the iron vessel of distilled water at 60° Fahr. is 94.112 lbs. avoirdupois. The vessel being emptied, carefully dried and warmed, and stood upon a hard rammed bed of dry sand with its neck perfectly level as before, was now filled perfectly level to the brim with molten cast iron. As the temperature of the vessel itself rapidly rose by contact with the large mass of molten

iron within it, and by its dilatation had its capacity enlarged, so the top surface of the liquid cast iron within it rapidly sank, fresh additions of molten iron being constantly made to maintain its top surface level with the brim. This was continued until the whole of the exterior of the vessel was seen to have arrived at a clear yellow heat, beyond which no increase to its temperature took place. At about twenty minutes after the molten iron was first poured into the vessel, this point was reached, the feeding in of additional iron being discontinued a few minutes previously. The whole being left to cool for three days, the vessel full of the now cold and solid cast iron was again weighed; on deducting, as before, the weight of the empty vessel, the weight of the cast iron which filled it was found to be 645.75 lbs., which, with certain corrections to be yet noticed, was the weight of cast iron which, when in the molten state, was equal to the capacity of the conical iron vessel in its expanded state due to its exalted temperature. We have now to determine what was the capacity of the vessel in this expanded state. The temperature at which cast iron melts may be admitted as about 2400° Fahr.; but as iron tapped from the cupola is always above its melting-point, we may admit that it was poured into the vessel at 2600° or 2700° Fahr., the surplus heat in the cast iron, whose mass was about four times that of the wrought-iron vessel which contained it, being given off in the first instance to heat the latter. The temperature at which wrought iron presents to the eye a clear yellow visible in daylight may, in accordance with the views of most physicists, be taken as between the fusing-points of silver and of gold, or at 2000° Fahr. The mean coefficient of linear dilatatian for 1° Fahr. of wrought iron has been determined between the limits of zero and 212° by Laplace, Smeaton, Troughton, and Dulong, the average of the four being 0.00000699 for 1° Fahr.; and this is certainly below the truth for the whole range of temperature up to fusion, as the rate of expansion of all fusible bodies appears to increase with the temperature. Rinmann has determined the linear dilatation of a bar of wrought iron, when raised from 60° Fahr. to a white or welding heat, to be $\frac{1}{80}$ of its length, or .0125; and taking the total range of temperature here at 2400°, we have a mean coefficient of linear dilatation $=0.0000052$ for 1° Fahr. This is a still smaller coefficient than the preceding; the author has, however, preferred to adopt it in order to avoid any pretense to exaggerate in his own favor the results arrived at. Applying, then, Rinmann's coefficient to the dimensions of the cone at 60° Fahr., and to its temperature (2000° Fahr.) when at the maximum, we are enabled to deduce the true capacity of the cone when expanded to the utmost and filled with molten iron, viz. $=2691.77$ cubic inches. The iron conical vessel was now cut off by a circular cut at the base and another up and down the side of the cone, and separated from the conical mass of iron that had filled it; the interior surface of the iron vessel was found in several places about the lower part of the cone in perfect contact with that of the cast iron which had filled it; but in other portions very slightly distant from it, as judged by the sound of a hammer upon the sides of the vessel before it was cut off. The cast iron was not adherent to the vessel anywhere. The cast iron cone being thus laid bare, had a V-shaped piece cut out of it (in the "slotting" machine), by two planes, each passing through the axis and meeting at an angle of about 60°. The conical mass proved perfectly sound and free from cavities or blow-holes anywhere, except very near the summit or neck, where there was found to be a hollow or cavity accidentally left during the feeding (as above described). By measurement the volume of this cavity was found to be$=$ 5.5 cubic inches; assuming this cavity filled with iron of the same quality as the cone, the weight of the latter would be increased by 1.43 lb., making thus the corrected total weight of the solid cone of cast iron $=647.18$ lbs. From the wedge-shaped piece cut out from the cone at half its altitude, and about half-way between the axis and circumference of the sector, a piece was cut out, the specific gravity of which, taken by the usual methods, proved to be 7.170, which may be taken as the mean specific gravity at 57° Fahr. of the whole of the cast iron that filled the cone. Reverting now to the conical vessel which con-

tained at 60° Fahr. 94.112 lbs. of distilled water, its capacity being 2605.5 cubic inches : this capacity was enlarged by expansion when filled with molten iron to 2691.777 cubic inches, so that the conical vessel when cold, if it had had the same capacity as when filled with liquid iron, would have contained 97.224 lbs. of distilled water. We have now all the elements necessary for calculating the specific gravity of the cast iron which filled the cone in its molten state, because we have the actual weights of equal volumes of distilled water and of molten iron. The final results, then, are, that whereas the cast iron which filled the cone had when cold (57° Fahr. a specific gravity, as above given, = 7.170, the same cast iron in its molten state, as poured into the cone, had a specific gravity of only 6.650—in this case thus proving that the density of cast iron in its liquid state is not greater but, on the contrary, very much less than that of the same cast iron at the temperature of the atmosphere. The quality of cast iron employed in this experiment was the fine, bright, close-grained metal usually employed by Messrs. Maudslay, Sons, and Field for their engine-castings, and consisted of

$\frac{1}{2}$ Best scrap*—all by weight.
$\frac{1}{4}$ Gartsherrie, } Scotch,
$\frac{1}{4}$ Coltness, }

It may be taken as a typical or medium example of all good gray cast irons. I have not been enabled to repeat this experiment with the white, rigid, and crystalline cast irons, such as are employed for projectiles and other purposes ; but as it is a recognized fact amongst iron-founders that these irons expand in the range of temperature between solidity and liquidity *much more* than do gray irons, so we may justifiably conclude that the decrease of specific gravity by fusion of these hard cast irons would be in even a greater ratio than that shown by the above experiment on gray iron ; and generally the author feels himself justified in concluding that it is not true that *any* cast iron is denser in the fused than in the solid state. Cold cast iron, therefore, does not float upon liquid cast iron of the same quality by reason of its buoyancy, but in virtue of some force which tends to keep it upon the surface of the molten metal in opposition to a very considerable want of buoyancy or tendency to sink by greater density on the part of the solid iron, which is, by the preceding results, $\frac{1}{13.8}$ of its weight, whatever that may be, and is probably even greater than this in the case of hard white cast irons. The author's chief object has been thus far rather to prove that the cause assigned by the writers already mentioned is *not* the true cause of the floating of solid upon liquid cast iron of the same quality.

What *is* the nature of the force which produces this curious phenomenon and often in direct opposition to gravity, is a different and a much more delicate and difficult inquiry, which he must leave to physicists to fully investigate. The following experiments, however, may be placed on record as tending to afford some little dawn of light upon the subject.

The following experiments were made with pieces of iron cast from cast iron of the same quality as that which filled the experimental cone, placed upon or immersed in molten cast iron of like quality with themselves, so far as such can be secured by "tapping" at nearly the same time from the same cupola charged with the same materials.

Before proceeding to describe these, it will be necessary to deduce from the cone experiment a mean coefficient of total cubic dilatation for the whole range between 60° and 2400° Fahr. for the gray cast iron employed in these experiments. The total dilatation was, as we have seen, such as reduced the specific gravity of the cast iron when cold (=7.17) to 6.65 when in fusion. The cubic dilatation was therefore in the inverse ratio of these numbers, or as 1000 : 1078; and dividing this increase in volume by 2340° Fahr., the total range of temperature, we obtaian for the mean coefficient of cubic dilatation of this gray cast iron for 1° Fahr. = 0.0000333, or approximately for its mean coefficient of linear dilatation $\frac{0.0000333}{3} = 0.0000111$. These coefficients are nearly double those obtained by Roy and by Lavoisier for a range of temperature of 180° Fahr.

*Disused and broken-up castings.

viz. between 32° and 212°, which is quite what we should expect, as the coefficient of dilatation in all bodies increases with the temperature.

We have seen from what precedes that two forces at least are concerned in the phenomenon of cold cast iron floating upon the same when liquid, viz :—

A. *Buoyancy* or its opposite, dependent upon the relation between the actual specific gravity of the cold metal and that of the liquid metal upon which it is placed, and whose absolute power for any given difference of specific gravity depends upon the *volume* only of the floating mass.

B. A *repulsive force* of some kind tending to repel the surfaces in contact of the hot and cold metals. Whatever be the form of the floating solid, this repulsive force can only be effected in producing flotation upon such surfaces of the floating solid as are parallel to the surface of the liquid metal, or at least so circumstanced that repulsions upon one surface, or part of a surface, are not equilibrated and nullified by repulsions upon others in the opposite direction. Thus if a parallelopiped float with one of its surfaces parallel to that of the liquid metal, the repulsions upon its immersed vertical sides, taken two and two respectively, are in opposite directions, and therefore nullified, and the bottom or horizontal surface is alone effective in producing flotation. So also if a cylinder float with its axis horizontal, the ends are ineffective, as is also all that portion of the cylindric surface immersed which is above the level of the horizontal diameter of the cylinder.

These preliminary explanations will enable us better to interpret the following experiments :

Experiment 1. An irregular piece, believed to be of hard and dense cast iron, and also a ball of about $2\frac{1}{2}$ in. diameter, believed to be of close-grained gray iron : both sunk to the bottom when thrown into the ladle of liquid iron, and remained for some time at the bottom ; both, however, reappeared upon the surface when they had acquired a temperature sufficient to have fused off portions of their respective masses.

In every fresh-lined ladle of liquid cast iron there are circumferential ascending and central descending currents in the metal, produced by the gases evolved from the lining, as hereafter fully explained. It is no doubt chiefly to these ascending currents that the heated ball in Experiment 1 owed its ascent to the surface ; for if the heating took place in perfectly motionless cast iron, there seems no reason why the place of the sunken ball should change up to the moment of complete fusion.

Experiment 2. Two parallelopipeds, each $2'' \times 2'' \times 6''$, were cast of close gray iron ; one of these was placed cold upon the surface of a large ladle of liquid iron of like quality ; the other was heated as hot as it would bear without distortion, viz. to nearly a bright yellow heat, in a forge-fire, and then placed upon the surface of the liquid metal. Both pieces floated, and, as nearly as could be judged, both to the same height above the liquid, namely 0.1808 in. The volume of the cold piece being 24 cubic inches, the ratio of the immersed to the emergent portions was 9.6 to 1, the effective surface upon which the repulsive force could act in producing flotation being 12 sq. in. Assuming that the heated piece has been raised from 60° Fahr. (the temperature of the cold piece) to 2000° Fahr., and applying the mean coefficient of cubic dilatation as above given to this range of temperature, viz. $2000° - 60° = 1940°$ Fahr., we find that its volume was enlarged to 24.75 cubic inches, or $=\frac{1}{32}$ of the volume when cold ; and taking the specific gravity of the cold piece to have been 7.17 (see *ante*), that of the hot piece would be reduced to 7.10 ; the effective repellent surface was slightly enlarged in the hot piece, and the immersed volume was to the emergent volume as 9.66 : 1. The buoyancy of the heated piece had been increased, or, more correctly, its *negative* buoyancy had been decreased, as compared with that of the cold piece, but yet it has sunk deeper into the liquid iron in proportion to their respective volumes. We may therefore be justified in concluding that the repellent force which kept both pieces afloat is diminished in energy in some proportion as the difference in temperature between the liquid metal and the piece floating upon it is diminished, and that where the liquid and the floating pieces are alike in quality of metal, both the negative buoyancy and the re-

pellent force must both disappear at the instant that the floating piece itself becomes liquid by heat abstracted from the molten metal.

Experiment 3. Two cylindric pieces of the same gray cast iron and of the same diameter (=2.375″) were gently placed with their axes horizontal upon the surface of the molten iron, the one being at 60° Fahr., the other at about 300° Fahr.; they both floated with a segment of the cylinder whose versed sine was 0.31 in. emergent. The volume of either cylinder was 22.15 cubic inches, and the emergent was to the immersed volume as 1 : 8.4. The effective repellent surface in each case (or cylindric surface below the horizontal diameter) was 18.65 sq. in.; but if we suppose, as in fact we have done, that the repellent force, whatever be its nature, acts everywhere perpendicularly to surfaces of contact of the solid and liquid, then the effective repellent surface here is only the difference between the immersed surfaces of the cylinder below and above the horizontal diameter, or 9.3 sq. in. From this we may perhaps conclude that the repellent force is mainly dependent upon the extreme upper parts of the range of temperature between the liquid and the cold body, inasmuch as an augmentation in temperature of the latter of 300°, or about $\frac{1}{8}$ of the entire range between solidity and fusion of the cast iron, produces no very sensible alteration in the tendency to float of the pieces.

Experiment 4. Three circular disks of the same gray cast iron, each of 6″ diam. by 0.375″ in thickness, were provided each with a slender iron wire eye, cast into the centre of one surface, so that by a hooked wire they could be gently laid upon the surface of the liquid iron of their own quality. The lower surface and edge of one disk were left as it came clean from the sand, those of another were rusted by wetting with solution of sal-ammoniac, and those of the third were ground smooth and polished by the grindstone. When the three disks were in succession laid upon the surface of the molten iron, they all floated alike as nearly as could be judged, each sinking to one half the thickness of the disk, so that the immersed was to the emergent volume in the ratio of equality: We may conclude from this that the condition of the metallic surface of the solid cast iron has no material influence upon its flotation.

Experiment 5. Two circular disks, provided with eyes as in Experiment 4, were prepared, the one being 6 in. in diam. by 0.375 in thickness, and the other 3 in. in diam. by 1.5 in. in thickness. The respective volumes of these two disks are the same, but the circular flat surfaces respectively are as 4 to 1. The surfaces of the two disks being as they came from the sand-mould, they were placed gently upon the surface of the molten iron: both floated with the same portion in altitude emergent. The larger and thin disk had, as stated in Experiment 4, its emergent and immersed volumes in the ratio of equality [or the emergent was to the whole volume as 1 : 2]. In the smaller and thicker disk, the emergent volume was to the immersed volume as 1 to 7. [Or the emergent volume was to total volume as 1 : 8; but 2 : 8 : : 1 : 4, or the emergent volumes are to the total volumes in each case respectively proportionate to the lower or repellent surfaces of the disk.]

Now the effective repellent surfaces are here those of the lower circles of the respective disks, and these surfaces are to each other in the ratio of 1 (the larger) to $\frac{1}{4}$ Whatever be the nature, therefore, of the repellent force, it seems to be proportionate to some function of the effective surface as already defined, and not to the immersed volume of the solid cast iron which floats upon a liquid less dense than itself.

In all these experiments the mass of the molten cast iron was large in proportion to the pieces placed upon it, and the surface was kept by careful skimming almost perfectly free from scoriæ or oxyde. A good deal of difficulty exists in observing the phenomena in such experiments as these, owing to the glare and heat of the molten metal. Whatever light these five experiments may throw upon the nature of the force which produces flotation, the subject must as yet be viewed as very incomplete. There are some facts of which no complete explanation can be offered without further experimental study; such as, for example, that a piece of cold cast iron which floats on liquid iron of its own

quality if forcibly thrust to the bottom and rapidly and at once released, rises again rapidly to the surface with all the *appearance* of a *buoyant* body, which it certainly cannot be.

From what precedes, however, we may summarize as follows :

If F be the force which keep the solid iron floating, B the buoyancy $\pm$ of the solid piece, and R the repellent force, then, in the case of a piece floating upon molten iron of its own quality, B is always negative, and $F=R-B$, the value of R for any given case depending upon the *effective surface* of the solid, and that of B upon its volume, both being modified by the initial difference in temperature between the solid and liquid metals. In the case of the solid being placed on liquid cast iron differing in quality from it, B may be either positive or negative, and R still dependent upon the conditions already stated. Hence in any such case we may have

$$F=R-B \text{ or } =R+B.$$

These conditions kept in view may clear up many phenomena at first apparently anomalous.

[However feeble may be the ascending currents, above referred to, upon the floating disks in Experiment 5, their effect must be viewed as proportionate to the lower surfaces, and therefore proportionate to the repellent force, and as possibly adding, though slightly, to its effect.]

The following experiments were made at the Royal Arsenal, Woolwich, with a view to ascertain whether any sensible expansive force could be recognized as due to the enlargement in volume by consolidation of a spherical mass of cast iron :—Two spherical bomb-shells, each of about 10″ in diameter and 1″.5 in thickness, whose external orthogonal diameters had been carefully taken when at atmospheric temperature (about 53° Fahr.), were both heated in an oven-furnace. One of these having been thus heated, but not to a *very* bright red, was permitted gradually to cool again, and its final dimension when cold noted. The other shell was withdrawn from the oven when at a bright red heat, and immediately filled to a little above the inner orifice of the fuse-hole with molten cast iron, the quality of this being the very dense mottled gray iron smelted at Elswick Works from the Riddesdale ores, and used in the arsenal for casting projectiles. The fuse-hole was closed by a screw-plug, which, however, did not reach within an inch of the surface of the molten metal, and the whole surrounded by a sheet-iron screen to keep off currents of air, was allowed to cool gradually, the dimensions being taken of the sphere as it cooled and contracted at intervals of half an hour until it had become cold. The enveloping shell was then cut through by the lathe in a great circle at right angles to the axis passing through the fuse-hole. One of the halves of the shell being detached, the interior surfaces of both hemispheres were found in perfect contact with that of the ball of iron they had contained, but no elastic tension seemed to exist in the shell. The ball of iron was drilled into and split by steel taper plugs, and sections of it exposed passing through the diameter in a line with the axis of the fuse-hole. There was no large cavity or "draw" anywhere in the interior, but there were two very small irregular cavities very near the fuse-hole; and the central portion of the mass embraced by an imaginary sphere of about 3″ in diameter, proved to be "spongy" and granular, as compared with the very dense and close-grained iron that constituted the remainder of the ball.

The following Table shows the course of contraction in dimensions of the filled shell and also of the empty shell in their progress of cooling :

[*See Table following page.*]

The object of heating and cooling the empty shell was to ascertain what amount, if any, of permanent enlargement it might suffer, it being a well-known fact that all solids of revolution of cast iron, and generally of all metals of sufficient rigidity, become permanently enlarged by being heated red-hot and permitted to cool. This arises from the fact that the outer *couches* of the solid (a sphere for example) are the first heated and expanded, and have to draw off more or less from the less-heated mass within. Tangential thrusts and radial tensions are thus produced in the material of the outer *couches* which disappear, or even become reversed, as the progress of heating reaches the in-

Time.		Diameter, filled shell.	Diameter, empty shell.
	Cold	9.850	9.843
11.30	Put in oven-furnace (shell to be filled)		
12.30	Put in oven-furnace (empty shell)		
12.15	Withdrawn from furnace	10.020	
12.55	Withdrawn from furnace	..	9.960
	After filling with iron, diameter was	10.030 10.040	
12.50	After filling with iron, diameter was	10.040	
1.20	After filling with iron, diameter was	10.020	9.955
1.50	After filling with iron, diameter was	10.000	9.950
2.15	After filling with iron, diameter was	9.995	9.875
2.45	After filling with iron, diameter was	9.980	9.865
3.15	After filling with iron, diameter was	9.978	9.860
3.45	After filling with iron, diameter was	9.976	9.855
4.15	After filling with iron, diameter was	9.975	9.854
4.45	After filling with iron, diameter was	9.973	9.862
5.15	After filling with iron, diameter was	9.970	9.852
5.45	After filling with iron, diameter was	9.968	9.851
6.15	After filling with iron, diameter was	9.965	9.851
6.45	After filling with iron, diameter was	9.964	9.851
7.15	After filling with iron, diameter was	9.964	9.851
7.45	After filling with iron, diameter was	9.963	9.851
8.15	After filling with iron, diameter was	9.962	9.851
	When cold	9.960	9.851

terior of the mass ; but in the subsequent cooling the entire train of forces is reversed, the exterior *couches* lose heat by dissipation first, and have to accommodate by tangential tensions their dimensions to the still hotter interior, the final result being that when the whole has cooled the dimensions are greater than before the solid was heated. A 32-lb. spherical shot, which is rather more than 6 inches in diameter, can be thus permanently increased $\frac{1}{10}$ of an inch in diameter, by a single heating. It is obvious that the increase will be much less in a spherical shell than in a solid sphere, and the less as the shell is thinner. On inspecting the Table it will be seen that the empty shell had its diameter thus permanently enlarged by 0.008 of an inch ; and had it been heated to as high a temperature as the filled shell, we may allowably conclude that this enlargement would have reached 0.01 of an inch. The filled shell has had its diameter increased by the decimal $0''.11$; and if we deduct from this the amount of permanent enlargement due to heating only, equal to that of the empty shell, we have the decimal $0.11-0.01=0.10$ which has to be otherwise accounted for. This shell was at a bright red heat visible in clear daylight when filled with the liquid iron, which occupied the spherical cavity and about 0.43 in height of that of the fuse hole. The temperature of the shell visibly rose by the heat communicated from the liquid metal, and in 30 minutes after it was filled had attained its maximum, the surface being then at a bright yellow heat in daylight when the first measurement of enlarged diameter was made. The successive measurements were taken for orthogonal diameters in the direction normal to the fuse-hole by means of finely graduated steel beam calipers capable of being read to 0.002 of an inch or even less ; the dimensions set down in the Table are the means of each pair of orthogonal diameters. The shell was thus heated at the commencement, and before consolidation of its liquid contents had taken place to any considerable extent, to within probably 200° or 300° Fahr. of the temperature of the cast iron within. The shell and its contents are therefore at the commencement very nearly in the same condition as though the whole were a sphere of molten iron without any more or less rigid envelope, if such could exist. Reverting to what has been said above as to the train of forces called into play in

a cooling sphere, let us consider what has taken place here. As the heat is dissipated from the exterior of the molten mass, being transmitted through the shell, one *couche* after another of the molten metal in contact with the inner wall of the shell consolidates, the thickness constantly advancing towards the interior, where the metal is still liquid. If each of these *couches* in consolidating expanded in volume, such expansion must conspire, with the contraction constantly going on by the abasement of temperature, to produce compression in the central and as yet unsolidified portion of the mass. If, on the contrary, each *couche* as it solidifies contracts in volume (and, as is the fact, by a larger coefficient of contraction for equal small ranges of temperature before and after solidification), then the effect must be that, after the solidified crust has attained a certain thickness and sufficient rigidity, the further progress of contraction of the central portions as *they* successively solidify must be met by their tending to draw off from the solidified shell, or in other words, by a drawing-off from each other of the particles of that central portion of the sphere which last solidifies. Now the latter is exactly what has happened: a portion of the exterior and first solidified crust, reaching about an inch and half inwards from the interior of the shell, was found to have a specific gravity of 7.150 at 57° Fahr., while a portion taken close to the centre of the sphere had a specific gravity of only 7.037; and this specific gravity would have been still lower (or, in other words, the central part of the sphere would have been still more "spongy") had it not been fed by drawing downwards a portion of the liquid iron which partially filled the fuse-hole, the portion so drawn down being estimated by the volume of the cavities left at 0.400 of a cubic inch; so that but for this the specific gravity of the central spongy sphere taken at 3″ diameter would have been reduced to 6.776.

If we reduce this central spongy mass of 3″ diameter and of the last mentioned specific gravity to a density as great as that found for the exterior crust, namely 7.150, the sphere of 3″ diameter would be reduced to one of 2″.138; and it is easy to see that in that case the external diameter of the whole sphere of metal and of the containing shell would have been less in a corresponding proportion, and that thus the final dimensions of the shell would have returned to what they were at the commencement, less the permanent enlargement, as measured by that of the empty shell. If there existed, on the other hand, any sensible expansion in volume of the metal in consolidating, not only would a central "spongy" portion be impossible and the central be the densest part of the whole sphere, but an enlargement of the entire mass and of the covering shell stretched by it must have occurred, so large as to be wholly unmistakable.

[The importance of the facts elicited from this experiment cannot be too forcibly laid before the reader. Had the sphere of molten iron, losing heat from its exterior, expanded in volume as *couche* after *couche* it solidified from the exterior, the solidification constantly advancing inwards, then the central portions of the sphere when ultimately solidified *must* be found to be the *densest* portions of the whole mass; the opposite of which was found to be the fact, the central portions of the experimental sphere being, as stated, the *least dense* portions of the whole mass. This alone seems conclusively to negative the supposition of any expansion in volume in cast iron in consolidating. On examining the Table, it will be remarked that between the hours 1.50 and 2.45 there is an irregularity in the progress of contraction which might be assumed to indicate a less rate of contraction within this epoch; and it might be further assumed that this apparent reduction arose from the conjoint action of general contraction and partial expansion operating together within some part of the mass; but this view, which the writer believes would be entirely incorrect, appears sufficiently negatived by the following considerations:

1. Between the hours 1.50 and 2.45 but one caliper measurement was made, namely at 2.15, and upon this one measurement both the existence and the amount of this anomalous part of the curve depend. An error in this single caliper measurement amounting to 0.006 of an inch was sufficient to have produced it; and as the limit of reading of

the beam calipers was to a limit of 0.002 or possibly 0.001 of an inch, a mistake in the measurement at 2.15, or a misreading of only the decimal .004 or .005 at most, is sufficient to account for the anomaly.

2. It does not necessarily indicate expansion, and from the early time of its occurrence, viz. only 1 hour 25 minutes from the commencement of cooling, it seems highly improbable that it could arise from partial expansion then commencing, while as yet a very large proportion of the entire mass must have been still liquid.

3. If it were really due to expansion, it must have shown itself later in a form that would have unmistakably declared its origin.

The supposition upon which Messrs. Nasmyth and Carpenter's theory rests may be divided into two distinct propositions.

1st. That cast iron is of greater density in the molten than in the solid state.

2nd. That cast iron in the act of consolidation expands in volume. These propositions are not identical, although the second is involved in the first. The first proposition has been already disposed of, and the last recorded experiments appear conclusively to disprove the second.

The phenomena described by Messrs. Nasmyth and Carpenter, and their explanation of the circulating currents observable in large and nearly cylindrical ladles of molten iron, *appear* at first sight so confirmatory of their views as to the greater density of cast iron in the molten than in the solid state, that it seems necessary here to present the true explanation of the facts, which, so far as they are here relevant, may be best given briefly in the words of these authors :

" When a ladle of molten iron is drawn from the furnace and allowed to stand at rest, the thin coat of scoria or molten oxyde which forms on the surface of the metal is seen, as fast as it forms at the circumference of the ladle, to be swept by active convergent currents towards the centre, where it accumulates in a patch. As the fluid metal parts with some of its heat and the ladle gets hot by absorbing it, this remarkable surface-disturbance becomes less energetic." This arises from " the expansion of that portion of the molten mass which is in contact with the comparatively cool sides of the ladle, which sides act as the chief agent in despersing the heat of the melted metal ; careful observation will show that the motion in question is the result of an upward current of the metal around the circumference of the ladle]. " The upward current of the metal can be seen at the rim of the ladle, where it is deflected into the convergent horizontal direction, and where it presents an elevatory appearance. It is difficult to assign to this any cause but that of expansion and consequent reduction of specific gravity of the fluid metal in contact with the sides of the pot, as, according to the generally entertained idea, the surface-currents above referred to would be in the contrary direction to that which they invariably take, *i. e.* they would diverge from the centre instead of converging to it."

The facts, so far as they are above described, are generally correct, but the explanation given is not the true one. The currents observable for some time after a large ladle (say, holding 10 tons) is first filled with molten iron are not produced by difference of temperature in different parts of the mass, but in the following way :—Such a ladle is of wrought iron, about half an inch in thickness ; and to preserve this tolerably cool, even for several hours, it is lined with a coating of earthy material daubed upon the interior in a tough and plastic state, from an inch to an inch and a half in thickness, and dried within it. The lining material consists of plastic clay, with a proportion of siliceous sand beaten up together with horsedung, chaff, plasterer's cow-hair, or other fibrous material, conferring toughness upon the mass when soft and porosity when dry. This material, after drying at a temperature averaging 500° to 700° Fahr., on being exposed to contact with the molten cast iron, exhales torrents of gas and vapor, which pass upwards through the molten mass and determine the direction of its currents ; and it will be obvious, on inspecting the figure, that these currents will be most powerful round the outer circumference of the mass, where each unit of its top surface has a larger proportion of lining in

proximity to it than at the central parts of the mass, where downward currents are the necessary consequence of those produced upwards at the circumference. The organic matters mixed with the lining are carbonized, and give forth the elements of water as well as nitrogen. The clay, which is a hydrous silicate of various earthy bases, gives forth its water and some of the oxygen of the peroxyde of iron which most clays contain. More or less carbonate of lime is almost always interspersed, and this gives forth carbonic acid and water. The gases thus streamed forth act mechanically by their ascent and also chemically upon molten iron, the water being decomposed, oxydizing portions of the iron and forming scoriæ, which is again more or less reduced by contact of the hydrogen and nitrogen when the latter is present. These rapid combinations and decompositions are no doubt the main cause of those singular vermicular startings referred to by Messrs. Nasmyth and Carpenter, which are familiar to every iron-founder, but which are entirely distinct from the ascending and descending currents due to the ascent of the evolved gases. That this is the true explanation is supported by the following facts :—1. After a large ladle has stood full of molten metal for some hours, and time has been given thus for the whole of the gaseous contents of the lining to be driven off, the ascending and descending currents cease to be perceptible, and if any currents at all can be discerned they are in the opposite directions. 2. If, after this, such a ladle be emptied of its contents, the lining remaining untouched and only coated with a thin shell of adherent cast iron [and oxydes and silicates of iron], and the ladle being again filled with molten iron, no such currents as at first are produced in the molten mass, the lining having been previously exhausted of its gases and vapors. That the currents described by Messrs. Nasmyth and Carpenter are *not* due to dissipation of heat from the mass through the sides of the ladle is evident from the following considerations :

A 10-ton ladle, which is about 4½ feet by 3 feet in depth, loses heat so slowly that after standing for 6 hours the molten metal is still fluid enough to make castings. Let us suppose it filled into the ladle at a temperature of 2800° to 2900° Fahr., and that after six hours it is still 200° above the temperature of solidification of cast iron, or at 2600°. The molten mass has thus lost 300° of heat in 360 minutes, or .0138 of a degree per second. We may assume this at any instant as representing the difference in temperature between two vertical columns, one at the centre and the other at the circumference of the molten mass. The linear dilatation of cast iron for one degree of Fahrenheit being 0.0000111, as deduced from its total cubic dilatation between 60° Fahr. and the temperature of fusion at which it was poured into the cone, as given in this paper and assuming the depth of the colder of these columns, whether that be at the circumference or not, to be, as stated, 36″, that of the hotter column will be 36.0000005514, and the difference between these two measures the force which alone can produce circulating currents in the mass by difference of temperature due only to cooling. This is equally true whether it be the colder column that is dilated, as supposed by Messrs. Nasmyth and Carpenter, or the hotter one, as is the fact. And if we consider the viscidity of molten cast iron, it is perfectly obvious that the circulating currents referred to by Messrs. Nasmyth and Carpenter cannot be due to so insignificant a cause.

Want of attention, or careless interpretation of the many and somewhat complicated conditions thus seen to be involved in the cooling of a solid by dissipation of its heat from its exterior has caused many serious misapprehensions on the part of experimenters as to the supposed expansion of metals in volume when consolidating. Thus, even in the case of bismuth, it has been supposed a conclusive proof of its expansion that a mass cooling in an open crucible exudes from its interior upon its top surface cauliflower-like excrescences ; but although the author does not here deny or affirm anything as to expansion being a fact in the case of bismuth, it is nevertheless obvious that such excrescences might arise merely from the grip of the crucible itself, or even of the exterior portions of the metal already solidified

contracting upon and so squeezing out portions of the still liquid interior.

It is stated on good authority that a distinguished artillery officer, in former years at the head of the Laboratory, Woolwich Arsenal, satisfied himself of the reality of the expansion of cast iron in consolidating by the following experiment :—An elongated projectile was cast, with its axis vertical, in a very thick and massive mould of cast iron, the mould being cold or nearly so ; the molten metal was introduced through a narrow aperture applied at the base of the projectile, the neck or "gate" being knocked off the instant the mould was filled. As the cooling rapidly proceeded, portions of the still fluid metal were forced out at the place where this neck was detached ; and the conclusion was come to that the exterior being already solidified such excrescence could only arise from expansion of the contained liquid metal as it solidified in succession. What really did take place, and is the true explanation of the facts, is, that when a very thick iron mould of this sort is suddenly heated by pouring molten iron into its interior, as the heat abstracted from the latter can only pass into the material of the mould at a rate determined by its conductivity, so the interior part rapidly becomes raised to a temperature enormously higher than the exterior portions, which for a time remain almost cold. The expanded interior walls of the mould push inwards as towards the points of least resistance, and so actually diminish the capacity of the mould for a time, the inner surfaces of which press upon the consolidating crust of metal within it, and so squeeze out in part its liquid contents, just as water might be squeezed from an india-rubber bottle.

It seemed desirable to obtain some experimental results in reference to the objects of this communication with lead. It has never, so far as the author is aware, been even suggested that this metal expands in consolidating. Its coefficient of dilatation by heat is enormously greater than that of cast iron, being, according to the determination of Lavoisier and Laplace, between 32° and 212° Fahr.=0.0000474 of its volume for one degree Fahr. ; so that, taking its fusing-point at 617° (Rudberg), and assuming the coefficient constant for the entire range from 60° to 617° (which is much below the truth), its dilatation when in fusion would be=0.0264 of its volume, and the specific gravity of lead at 60°=11.36 ; that of liquid lead must be *below* 11.07. Indeed this enormous amount of dilatation is impressed upon any observer who sees the rate at which the lead in casting a common bullet sinks into the neck of the mould, and the comparatively large cavity which always exists in the ball when cut in two. From its low temperature of fusion and the suddenness with which lead passes from the solid to the liquid state without any phase of intermediate viscidity, and only a brief one of crystalline brittleness, and the facility with which its surface can be kept free from dross or oxyde, this metal presents a "crucial" example for experiment in reference to our subject.

The following experiments, by the kind permission of Messrs. Pontifex & Wood, London, were made at their works :

1st. Upon the surface of a large pot of melted lead, the temperature of which was estimated at from 750° to 880° Fahr., the half of a large pig of newly smelted lead, being a semicylindrical bar of about $5'' \times 2\frac{1}{2}''$ and about 18″ long, was gently laid down horizontally ; it immediately sank to the bottom and there remained. When about half its volume was melted away, the unfused portion was drawn up to the surface and let go, when it at once sunk to the bottom again.

2d. A ball of such lead was cast, weighing $17\frac{1}{2}$ lbs., diameter about $4\frac{1}{2}''$; this was put into an empty hand-ladle, which was gently placed upon the surface of the pot of melted lead; the ladle was depressed sufficiently to fill with lead, and being left free was carried to the bottom of the pot with sufficient impetus to produce a sensible blow of the exterior of the ladle upon the bottom of the pot.

3d. A flat circular disk of about 1.25 inch in thickness, being laid gently upon the surface, after a moment's hesitation slowly went to the bottom. Another disk of 6″ diameter, by rather less than an inch in thickness, remained a few seconds longer on the surface and then sunk to the bottom ; both disks, while

they floated, had their top surfaces but very slightly elevated above that of the liquid lead. One of the disks being gently lowered into the liquid lead vertically and edgeways, at once went to the bottom.

4th. Two disks, each 6″ diameter, the one 0.57 inch and the other 0.4 inch in thickness, being gently laid flat upon the surface of the molten lead, floated, and with an emergent portion sensibly greater than that of the disks in experiment 2 and 3, and remained floating until about 1.25 of the radius had been melted away all round, when they slowly sunk in the liquid, as was proved by the slow disappearance of the slender iron wire cast into the middle of the disk for the purpose of lowering. The thinner of these two disks floated rather longer than the thicker.

5th. A plate of sheet or laminated lead, clean from the rolling-mill, of about 0″.5 in thickness and about 10″ square, being gently placed flat on the surface of the liquid lead, floated, its top surface being nearly level with that of the liquid. After about ten seconds a piece was melted off from one of the edges, when the plate canted in the opposite direction and sunk.

6th. Plates of about 0″.18 thick floated much in the same manner as the preceding. The temperature of the solid lead employed was in all cases about 70° Fahr.

It follows from these experiments that, as in the case of cast iron, the solid does not float upon the liquid lead through buoyancy, that, on the contrary, the negative buoyancy is very marked, and that the repellent force, whatever be its nature, by which flotation is produced is dependent upon the effective surface as compared with the volume of the solid.

They present also a corroboration of the view that the repellent force upon the unit of effective surface is greater as the difference of temperature between the solid and liquid metal is so.

I proceed to some remarks upon the experiments referred to at the commencement of this paper, and quoted by Messrs. Nasmyth and Carpenter, as to the floating of pieces of solidified iron furnace-slag upon the same slag when in the liquid state. It is a fact that blast-furnace slags cooled below the point at which they become rigid do very generally float upon the same slag in its molten state. It is equally true that the basic silicates which constitute the chief part of terrestrial volcanic lavas float upon the surface of these when molten. But these admissions do not suffice in any degree to support the conclusion deduced by Messrs. Nasmyth and Carpenter, that basic silicates, whether as furnace-slags or lavas, are denser in the molten than in the solidified state, nor that these bodies in the act of solidification expand in volume or decrease in density in any manner, irrespective of the formation or enlargement of cavities or gas-bubbles within them. The experiments of the author upon the total contraction of iron furnace-slags for the entire range of temperature between that of the blast-furnace and the atmosphere, made at the Barrow Iron-Works, and fully described in the author's paper on "The Nature and Origin of Volcanic Heat and Energy," printed in Phil. Trans. for 1873, leave no doubt as to the following facts:

1st. That the density of such slags at 53° Fahr. is to their density when molten and at the temperature of the blast-furnace as 1000 : 933, or, taken at the melting-point of slag, as 1000 to 983—molten slag being thus very much less dense than the same when solidified.

2d. That no expansion in volume whatever occurs in such slags at or near the instant of solidification.

The experiments of the author above referred to were made by filling cast iron slightly conical moulds with the slag run direct from the blast-furnace, and permitted to consolidate and cool therein, by which perfectly solid slightly conical blocks were obtained. From the method employed, and the very large scale upon which these experiments were conducted, it is *impossible* that any expansion in volume at or near the point of consolidation, if even of a very minute amount, could have occurred and yet have escaped notice. It is only necessary for the author here to point out that the floating of crusts of slag or lava is *not* due to the cause assigned by Messrs. Nasmyth and Carpenter; nor is it his intention to enter at any length into what are the causes of such floating when it occurs.

The following remarks, however, may be made :—It is impossible to obtain a moderate-sized fragment of solidified slag or lava free from air bubbles, and from involved or superficial cavities, which tend to float the mass when thrown upon its own material in the melted state. Those who have attentively watched large volumes of slag issuing from the blast-furnace are aware that it comes forth carrying with it a large volume of gaseous matter minutely diffused, which is pretty readily separated, and is characterized by a white vaporous cloud floating thinly over the issuing stream ; if the slag be cooled rapidly, the gaseous or vaporizable bodies present become confined and render the mass vesicular, while if cooled more slowly, and with a free surface for the escape of these, the mass solidifies more solidly, often as solidly as a block of granite.

Independently of the buoyancy that is produced by the vesicularity of rapidly cooled slags, it is highly probable that relatively cold and solid slag, whose buoyancy is negative, may yet float on molten slag, whose density is less than its own, in virtue of that same repellent force which, as we have seen, acts under like conditions in the case of metals.

With respect to acid silicates, or slags analogous to glass (which, however, are not referred to by Messrs. Nasmyth and Carpenter), the author again refers to the results given in his paper (Phil. Trans. 1873). These, and indeed the circumstances attending the production and destruction of the well-known "Rupert's drops," incontestably prove that these silicates also are *less* dense in the molten than in the solid state, and that they contract violently at or near the instant of consolidation.

The author has more than once heard the opinion expressed by those engaged about blast-furnaces, that their slags do expand in consolidating, based upon a misinterpretation of the following frequently occurring circumstance : When the large parallelopipeds of slag (5 to 6 feet square by 2 to 3 feet thick) are stripped from the iron square frame which formed their edges, and are being removed upon the iron wagons on which they are cast, and still, as often happens, in a very hot state, or even with a still liquid or viscous interior, though rigid externally, it occasionally happens that such a block bursts asunder, and with a suddenness which is sufficient sometimes to scatter dangerously some of the liquid interior ; or if the fracture be not so sudden, and the interior be in a viscous condition, the latter may continue for a considerable time to slowly exude in fantastic shapes from any aperture of escape left free to it. These facts have been supposed to indicate that the interior of the mass expands in consolidating. It is scarcely necessary here, however, to enter into any detail to prove that the phenomena are due to the contraction of the already solidified exterior upon the unyielding interior of the mass ; the former becoming fractured by its own grip, and its material being highly elastic, often yields with apparently explosive violence like a suddenly broken spring.

[The following remarks may be made, in addition to those preceding, in contravention of the supposed expansion of slags or lavas in consolidating. It is well known that masses of mud when dried by the sun crack, the fissures penetrating nearly perpendicular from the surface and separating into more or less symmetrical prisms. Blocks of starch after desiccation present similar phenomena, which are also frequently seen exemplified by the uppermost beds of argillaceous limestone (or calp) of Ireland when first laid bare from its detrital covering. In all these cases there can be no doubt that the phenomena are due to the shrinkage of the mass in drying. But shrinkage or contraction by cooling and consolidation ought to present us with like results ; and these we see actually manifest in the splitting-up of basalt into columnar prisms whose long axis are always found perpendicular to the surface by which the heat of the mass was dissipated. Such columnar separation is not confined to basalt ; instances of it are abundant in lavas of every age, the surfaces of the prisms in these being sometimes straight, sometimes curved. Although much remains yet to be investigated before all the circumstances attending the splitting-up of masses of basalt or lava can be said to be fully understood, yet enough is already known and clearly explained to make it certain that it is due to *contrac-*

tion of these materials as they cool; and that this form of splitting-up is wholly incompatible with that of any fissuring that could arise from the refrigeration of a mass the volume of every part of which expanded in consolidating.]

As in what precedes the hypothesis upon which the lunar volcanic theory of which Messrs. Nasmyth and Carpenter rests is proved to be without foundation, it seems needless to enlarge upon the incongruities and contradictions which the theory itself presents when fairly applied to such knowledge as we have of the volcanic features of the moon, or still more when applied, as it must be were it true, to those of our earth [assuming the materials of our earth and satellite analogous in their physical and chemical properties — an assumption made by these authors throughout their work, though without any attempt to support it by truth].

ON HYPERBOLIC WHEELS.

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Written for Van Nostrand's Magazine.

The article on spiral wheels, published by me in the *Franklin Journal*, Philadelphia, March, 1875, brought forward a lively private correspondence from which it appears that several gentlemen of high scientific attainments took considerable interest in this matter. One of these gentlemen makes the following remarks in his letter: "It is to be regretted that in addition to your article on spiral wheels the hyperbolic wheel, bearing so much resemblance with the former, was not treated by you in a similar way. Most books* that I have examined and consulted on this subject give a number of formulæ, the derivation of which is, however, not demonstrated," &c. Now, as similar remarks had been made to me by students who were desirous to study this subject more in detail, I prepared, therefore, some time ago, several diagrams, and derived some formulæ which, in my opinion, make the subject clear, and which, in order to accommodate such taking an interest in it, I shall present in the subsequent treatise.

1. HYPERBOLAID OF REVOLUTION.

The surface of this body, that is used for hyperbolic wheels, is generated by the revolution of a right line about an axis to which it is not parallel and which it does not meet. Let $a\,b$, $a_1\,b_1$ be a right line (Fig. 1) revolving about $c_1\,d_1$ as an axis horizontally projected at m. The extremity o of the perpendicular $m\,o$ of the two lines will describe the

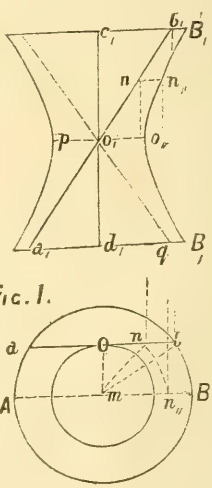


Fig. 1.

circumference of a circle called the gorge circle, and the extremities of $a\,b\,a_1\,b_1$ describe circles called the upper and lower discs. Any other point like $n_1\,n_1$ generates the circumference of a circle belonging to the surface of revolution, and when turned into the meridian plane will be projected at n_{11}. In this manner any number of points of the curve $B_1 o_{11} B_1$ can be obtained; if this curve is then revolved about $c_1\,d_1$ the hyperbolic surface is produced. It is proved (Church's Dis. Geom. pp. 58 and 59) that the curve

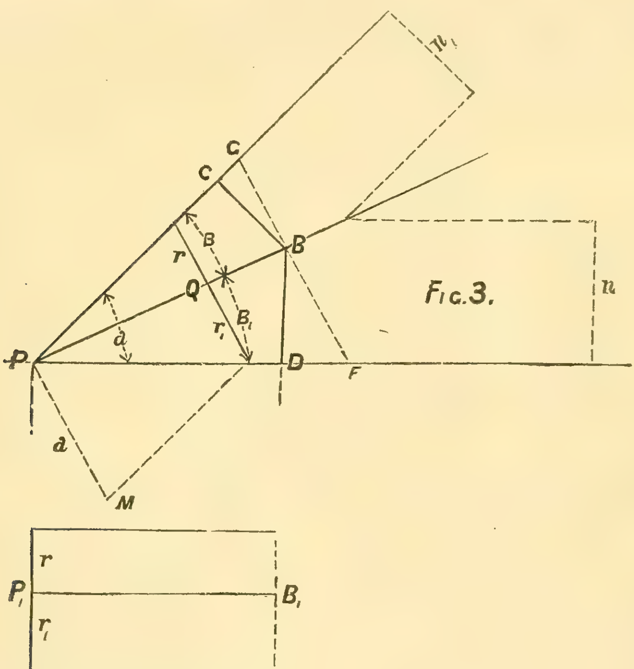
* Mr. Willis in his Principles of Mechanism gives a very thorough demonstration; but does not illustrate it by numerical examples.

$B_1 o_{11} B_1$ is a hyperbola and the lines $b_1 o_1$ and $o_1 q$ when projected on the meridian plane are the respective asymtates.

If the same line ab, $a_1 b_1$ revolves about another fixed line not in the same plane with it,* a second surface of revolutions will be generated tangent to the first along the generating line, and if the two solids of revolution in contact are placed in frames and motion is given to one of these it will be imparted to the other by partly rolling and sliding contact.

Suppose P D and P C to be two hyperboloids along the line P B, the axis P D and P C to be parallel to the vertical projection plane. We have then for the axial distance at P (Fig. 1), $a=r+r_1$, equal to the sum of the radii of the two gorge circles containing the point of contact at P. If a plane $P_1 B$ is passed through P_1 perpendicular to the axial line it will contain the element of contact, as this plane is parallel to both axes P C and P D (Fig. 3). Now to fix the position of P B we must know either the numbers of revolution or the numbers of teeth of both bodies. Suppose n and n_1 to be the numbers of revolution, and

* The position of this second axis can, however, not be taken arbitrarily as shown in the following figures 2 and 3.



N and N_1 the numbers of teeth of the bodies of revolution of which P C and P D are the respective axes. It is then $n : n_1 :: N_1 : N$, and if we assume B to be the point of contact of the upper discs, we have also :

$BC = PB . \operatorname{Sin} \beta$ and $BD = PB . \operatorname{Sin} \beta_1$ which gives

$$\frac{BC}{BD} = \frac{\operatorname{Sin} \beta}{\operatorname{Sin} \beta_1} = \frac{n_1}{n} = \frac{N}{N_1}. \qquad (1)$$

It appears then from (Fig. 3) that the angle d is divided in such a manner that the lines B D and B C, which represent the sines of β_1 and β respectively are in an inverse ratio to the numbers of revolution and in a direct ratio to the numbers of teeth.

If we put for $\beta = d - \beta_1$, we obtain :

$$\frac{\operatorname{Sin}\ (d-\beta_1)}{\operatorname{Sin}\ \beta_1} = \frac{n_1}{n}\ ;$$

Developing the first number we have,

$$\frac{\text{Sin } d. \ \text{Cos } \beta_1 - \text{Sin } \beta_1. \ \text{Cos } d}{\text{Sin } \beta_1} = \frac{n_1}{n}. \text{ Hence}$$

$$\text{Cotg } \beta_1 = \frac{\frac{n_1}{n} + \text{Cos } d}{\text{Sin } d}. \quad \text{That is :}$$

$$\text{Tang } \beta_1 = \frac{\text{Sin } d}{\frac{n_1}{n} + \text{Cos } d} \qquad (2)$$

Since the axial distance $a = r + r_1$ is perpendicular to the line of tangency, we obtain graphically the lengths of r and r_1 when we erect $PM = a$ perpendicular to PB (Fig. 3), and move PM parallel to itself till it lies between PC and PD. It appears then that $r = PQ$ tangent B_1 and $r_1 = PQ$ tangent B_1, which gives :

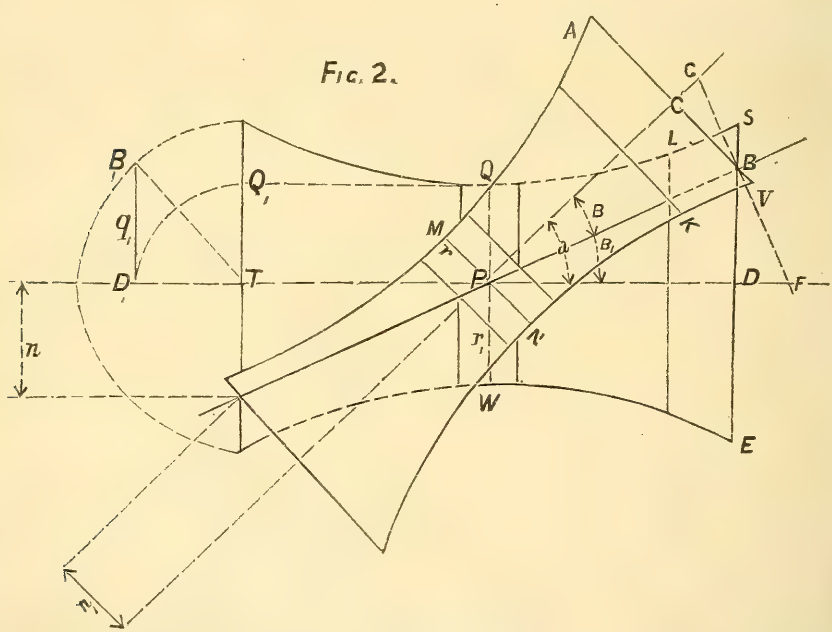
$$\frac{r}{r_1} = \frac{\text{Tang } \beta}{\text{Tang } \beta_1} = \frac{\frac{\text{Sin } d}{\frac{n}{n_1} + \text{Cos } d}}{\frac{\text{Sin } d}{\frac{n_1}{n} + \text{Cos } d}} = \frac{\frac{n_1}{n} + \text{Cos } d}{\frac{n}{n_1} + \text{Cos } d} \qquad (3)$$

but $r_1 = a - r$ introduced into (3) we find:

$$\frac{r}{a} = \frac{1 + \frac{n}{n_1}. \ \text{Cos } d}{1 + 2\frac{n}{n_1}. \ \text{Cos } d + \left(\frac{n}{n_1}\right)^2} \qquad (4)$$

These equations then determine the respective radii of the gorge circles and point of tangency when the axial distance $= a$, and the respective numbers of teeth or numbers of revolution N_1 N and n_1 n are known.

Fig. 2.



Finally, it is required on the other hand to find the two radii of the upper discs as C V and D S (Fig. 2), which may be obtained in the subsequent manner. Since the plane P_1 B_1 contains the line of contact—P B passing through the line of tangency which latter contains the points of contact P and B. Therefore $DB = D_1 B_1$ and $TQ = PQ = r_1$ (Fig. 2).

Hence if the line $PB = l$ is assumed, we find :

Since $DB = PB$. $\quad \text{Sin } \beta_1 = l. \times \text{Sin } \beta_1 = q_1 = D_1 B_1$

$$\left.\begin{array}{l} R_1 = DS = TB_1 = \sqrt{r_1^2 + q_1^2} \quad \text{and} \\ R = CV \sqrt{r^2 + q^2}; \quad \text{where } q = l. \ \text{Sin } \beta. \end{array}\right\} (5)$$

Introducing into the above derived general formulæ, particular angles we obtain, for example, $d=90°$ from (4).

$$\frac{r}{r_1}=\text{tang}^2\ \beta=\left(\frac{n_1}{n}\right)^2 \quad (6) \text{ and}$$

$$\left.\begin{aligned} &\frac{r}{a}=\frac{n_1^2}{n^2+n_1^2} \\ &\text{and on the other hand} \\ &\frac{r_1}{a}=\frac{n^2}{n_1^2+n} \end{aligned}\right\} \quad (7)$$

For $d=O$ the hyperbolic wheels pass into common spur wheels.

The subsequent numerical example will explain the use of the preceding formulæ, and how they are applied in constructing these wheels.

1. *Example.*—Given the axial distance $a=10$ inches and $\frac{n_1}{n}=\frac{1}{2}$; further the axial angle of projection $d=60°$. It is required to find the radii of the gorge circles and upper discs, also the position of the line of contact.

To find r and r_1 we have from formulæ (4)

$$\frac{r}{10}=\frac{1+2.\text{Cos }60}{1+2.\ 2\ \text{Cos }60+4}=\frac{1+1}{3+4}=\frac{2}{7}; \text{ hence}$$

$$r=\frac{20}{7}=\text{inches, and } r_1=10-\frac{20}{7}=\frac{50}{7}\text{inches}$$

To find β and β_1 we have from (2)

$$\text{Tang } \beta_1=\frac{\text{Sin }60}{\frac{1}{2}+\text{Cos }60}=\frac{0{,}866}{\frac{1}{2}+\frac{1}{2}}=0{,}866.$$

Hence

$\beta_1=40.°\ 53'$ and $\beta=60-40°\ 53=19.°\ 7'$.

Assuming the distance from the points of tangency of the gorge circles and the upper discs $l=18$ inches, we find from (5).

$$R_1=\sqrt{(18.\ \text{Sin }40.53)^2+\left(\frac{50}{7}\right)^2}=13{,}8 \text{ in.}$$

$$R=\sqrt{(18.\ \text{Sin }19.7)^2+\left(\frac{20}{7}\right)^2}=6{,}52 \text{ in.}$$

2. *Example.*—Given $N=15$ and $N_1=27$ (number of teeth), further the axial distance $a=5$ inches, and the axial angle $d=90°$, also the length of line of contact $l=12$ inches. It is required to find the radii of the gorge circles and those of the upper discs and the pitch. To perform the division of the angle $d=90$ into β and β_1, we have from (6):

$$\text{Tang}^2\beta=\left(\frac{n_1}{n}\right)^2=\left(\frac{N}{N_1}\right)^2=\left(\frac{15}{27}\right)^2 \text{ whence}$$

$$\text{Tang } \beta=\tfrac{5}{9}=0{,}555\ldots \text{ Hence}$$

$$B=29.°\ 3' \text{ while } \beta_1=d-\beta=60°-29.°\ 3' =40°\ 57'.$$

To obtain r and r_1 we have from (7), and since $n_1=\frac{5}{9}\ n$.

$$\frac{r}{5}=\frac{(\frac{5}{9}\,n)^2}{n^2+(\frac{5}{9}\,n)^2}=\frac{(\frac{5}{9})^2}{1+(\frac{5}{9})^2}=\frac{25}{106}$$

Hence $r=\frac{125}{106}=1{,}18$, while $r_1=5-1{,}18=$ 3,82 inches.

To find the two radii of the upper discs in contact, we have the perpendicular distances from the point of contact to the respective axis:

$$q=l.\ \text{Sin }\beta=12.\ \text{Sin }29°\ 3. \quad \text{Hence}$$

$$R=\sqrt{(12.\ \text{Sin }29\ 3)^2+(1{,}18)^2}$$

$$\text{and } R_1=\sqrt{(12.\ \text{Sin}40°57')^2+(3{,}82)^2}$$

which gives

$R=6{,}08$ inches, and $R_1=11{,}8$ inches.

If instead of l_1 the radius of one of the discs is assumed, for example, R_1, we find:

$$q_1=l.\ \text{Sin }\beta_1=\sqrt{R_1^2-r^2} \text{ and since } \frac{q}{q_1}=\frac{n_1}{n}$$

$$q=\frac{n_1}{n}\cdot q=\frac{5}{9}\cdot q$$

To find the pitch of each wheel:

$$p_1=\frac{2\ \pi.\ 11,\ 8}{27}=2,\ 74 \text{ inches, and}$$

$$p=\frac{2\ \pi.\ 6,\ 08}{15}=2,\ 54 \text{ inches.}$$

While two spiral wheels in contact have only one point common, it appears that two hyperbolic wheels touch along the whole element, and while the sum of the tangential angles and axial angle of two spiral wheels in contact amounts to 180°; the axial angle of the hyperbolic wheel limits the tangential angle, which indicates that a less number of varieties of hyperbolic wheels is

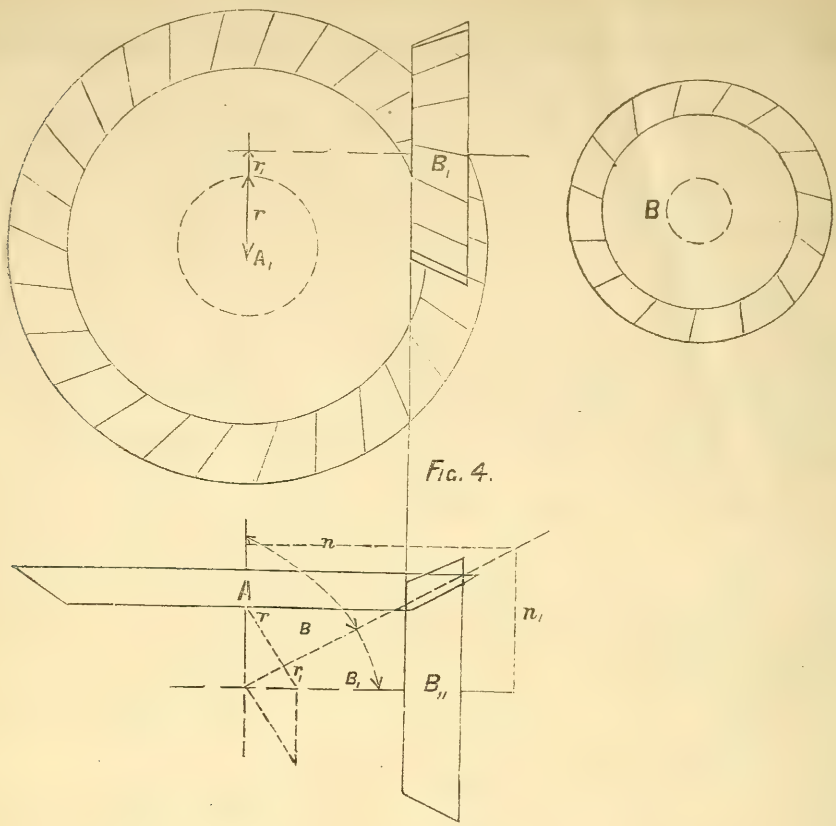


FIG. 4.

possible than of spiral wheels, a fact that has often been overlooked in applying these two kinds of wheels.

In practice, as in the case of conic wheels, a narrow frustrum only is required of each hyperboloid (Fig. 4), and these parts include so small a portion of the curve that straight lines may be substituted without sensible error. Several wooden models, which were made in accordance with the above calculation, work very well; some of them work by friction only produced by the pressure upon the surface of contact, others were furnished with teeth of a similar form to those of conic wheels.

As to the axial positions, the hyperbolic wheels bear much analogy with spiral wheels. The above (Fig. 4) represents the above mentioned thin frusta where the positions of the teeth are indicated by right lines obtained from the common line of contact.

Spanish Mining.—In the mining district of Mansilla, Logrono, Old Castile, two Ferroux rock-drills, to be worked by steam power, are being put up by the Swiss firm of B. Roy & Co., of Vevey. The scarcity of labor is much felt in the mining districts of Spain. The *Revista Minera* states that these two rock-drills are the first drills that have been yet used in the country. Great animation is reported from the mining district of Teruel. By a decree of the Governor of Biscay the exportation from Bilbao is prohibited of gunpowder, sulphur, saltpetre, dynamite, petroleum, lead, raw or worked, brass, tin, tin-plate, copper and iron, whether ore or metal, and every class of coal. By royal ordinance of June 12th, steel rails pay the same import dues with iron ores. The directors of the mining undertaking of the basin of Belmez and Espiel are endeavoring to obtain a railway direct between Madrid and Ciudad-Real.

THE CHANNEL TUNNEL—POSITION OF THE ENTERPRISE.

From "The Builder."

At length this vast enterprise, which, if completed, will certainly confer upon the engineering genius of the nineteenth century a conspicuous fame, has a chance of triumph over all the obstacles that have been predicted. The latest measures in connection with the project have been of the utmost importance. A bill has passed the two Houses of Parliament, authorizing the acquisition of certain lands in the parish of St. Margaret at Cliffe, in the county of Kent; and, at the same time, the French Assembly, before its dispersion, gave at least nominal effect to a scheme for opening similar works on the opposite shore of the British Channel at Sangatte. Neither in the English nor in the French Reports or Bills is there found a full explanation of the plans, as they lie now, in manuscript, at the Board of Trade; but an examination of the documents, or the raw official materials of which they are composed, suffices to inform us as to the actual state of the question. It is simply this:—In the year 1862 a company was incorporated to construct an underground, and also submarine, tunnel between England and France, with all necessary approaches, accessories, and conveniences, so as to afford the means of perfect land communication between the two countries, and the powers it proposed to claim were legally justified. It would be superfluous to enter upon the legislative wranglings over plans, acts to be abolished or construed, purchases, and costs, since the principal importance of the subject to the public consists in the mighty mechanical work to be undertaken. This will not be, at the outset, it may be as well to explain, an attempt directly to tunnel beneath the Channel for a railway line. It is only contemplated, according to the last statements deposited at the Board of Trade, to examine into the probabilities, or possibilities, of opening a way for the locomotive and the train at a safe depth below the sea. The present idea, then, is to sink, on both sides of the Channel, at particular points which are indicated, shafts through the gray chalk, or that which is almost nonporous and impermeable by water, and thence to conduct an excavation tending to meet from opposite ends, which should equal,—as it would, if triumphant, more than equal,—the perforation of Mont Cenis. However, the lawyer's aspects of the question are, at this stage, of little importance; the two Governments are agreed, and the thing has now only to be done. But what millions have been sunk in an effort to cross the British Channel, and conquer that "thin streak of sea-sickness" which, as popular tradition still asserts, frightened the famous Boulogne flotilla! Leaving out of consideration four of the Channel ports,—Hamburg, Rotterdam, Antwerp, and Ostend, as well as Havre and Dieppe, upon which this achievement, by the way, would not inflict any great injury, because they are commercial, rather than passenger, ports,—it is the narrowest sea which is the most formidable, which is, indeed, the "moat" of the Continent. The sufferers who, in default of a subway or drawbridge, endured the tortures of this brief passage, amounted last year to nearly half a million, and no number of *Castalias* or *Bessemers*, no matter how scientifically built, can meet the demand for those who feel an ineradicable hatred of salt and swelling water. There are excellent steamers, no doubt, employed upon the Channel service already, but where and what are the harbors? It is not the mere Channel passenger who finds himself inconvenienced. The invalid from Australia, or India, often declares that this bit of chopping sea-current is the most trying part of his voyage. He hates it worse than the rollers of the Atlantic, or the sultry nights of the Red Sea. Thus affirms, at any rate, Captain Tyler, whose report is in course of preparation for the next session of Parliament. His estimates concerning this little water journey between France and England are of peculiar interest. There is an average, he says, in the course of the year, of thirty storms; of 100 days bringing with them heavy seas and troublesome breezes; of 108 moder-

ate days happening in succession; and 90 of cold weather. The two opposite coasts, so to speak, are hostile in character,—what with their cliffs, bars, sands, necessity for breakwaters, masonry, piers, curves, capes, and shallows; and the problem has been, for many years, how to avoid the dilemma so long felt. Calais is, undoubtedly, so to speak, the English harbor of France. It may be, geographically, a little less direct on the road to Paris than Boulogne; but it has been selected, whether for one reason or another, as the great centre of communication, by way of Brussels and Cologne, for Strasburg, the Rhine, the North of Europe, and North and South Germany. There is nothing, therefore, to be wondered at in the circumstance that so constant desire should have existed, or so continuous an endeavor been made, to abridge and facilitate this traffic, which, it may be said without exaggeration, is vital to the common life of Europe.

In the first place, however, it was deemed necessary to ascertain the probability of successful excavation. Geologically, the bed, and, nautically, the depths, of the Channel, are well known; yet sufficient has been ascertained, in other respects, to induce an opinion that the experiments should be undertaken, not precisely at Calais, but at a point near Ambleteuse, near the familiar village of Andresselles, where the deepest water, near that coast, is to be found. Originally, as every one is aware, the project was regarded as an impossibility, and enormous steamers, or ferry-boats, were suggested, which would have involved a world of new piers, basins and sluice-gates; indeed, the fluctuations of ideas upon the subject has been the chief cause of its being left so long to wither in the pigeon-holes of speculation. After the great ferry scheme had broken down, the designs of Mathieu, the French engineer, for a Channel tunnel were deliberately brought upon the carpet, but as deliberately brushed away; for they were lost, and have never been recovered. Gamond came next, with a series of geological demonstrations, which have sustained the criticisms of time and science, and, at his instance, a Commission was granted by the late Emperor of the French, "which," in the language of the report, "appears to have come to the conclusion that it was desirable to test his investigations by sinking shafts and driving short headings under the sea, at the joint expense of the two Governments." But this is a French rather than an English view of the matter. Another countryman of our own, Mr. Low, also laid a plan before the Emperor, in 1867, as Sir John Hawkshaw had done, with even more elaboration, in the previous year, and Mr. Remington in 1865,—and their rivals, whose names deserve to be noted, although their ideas cannot be here described at length, were, —MM. Franchot, Tessier, Favre, Mayer, Dunn, Austin, Sankey, Boutet, Hawkins Simpson, Boydon and Brunlees. It is worth while to observe the list, because, if the work has not yet been accomplished, it has evidently not been for want of ingenuity and will. It has miscarried, however, to a certain extent, through the variety and contradiction of the schemes projected. Apparently, this difficulty has been overcome, and the resolve has been arrived at definitely to pierce the stiff gray chalk. Mr. Remington, as appears from the printed remarks forwarded by him to the Board of Trade, would have selected the line from Dungeness to Cape Grisnez, in order to avoid the chalk and fissures which he dreads encountering in the bed of the Channel, and to work in the Wealden formation, which he believes would afford a greater chance of success. Such is the latest aspect of the matter, as presented to the Department at Whitehall. But the report does not stop short here. It recapitulates the dreams, as some of them may indeed be termed, of other adventurous engineers. There were two or three who proposed bridging the Channel, and one actually professed himself prepared to build a "marine viaduct" from Dover to Cape Grisnez, with iron girders propped on 190 towers, 500 ft. apart, and 500 ft. above the water, and he estimates the cost of such an edifice at simply £30,000,000! Again, there was, as already mentioned, Mr. Hawkins Simpson, with his submarine tunnel on a pneumatic system, called by him, however, the "Eolian" principle, for which he claims the merits of cheapness, expedition, superior ventilation, and easier utility. It is interesting to

note the inexhaustibility of inventors in these respects. There is Mr. Alexander Vacherot, who has submitted to the Board of Trade a scheme which, we ought to say, he laid before the Emperor of the French in 1856, for "laying on the bed of the sea a tunnel made, or formed, so as to constitute, so to speak, a monolith." He would "construct it on the shore," and "complete it in sections, to be drawn down into their places when finished."

The representative officer of the department dismisses most of these projects with a critical, yet downright, denial of their practicability, and his language may be worth quoting :—"Although it was desirable to advert to these various expedients, it is not necessary, in this place, to say more in regard to them, than that, while I am unable to convince myself of the feasibility of any bridge scheme, I conceive that it might be wise to test the practicability of a tunnel by means of preliminary driftways." This is precisely what it has been agreed, by both Governments, both Legislatures, and the united companies, shall be done. It is true that not far from forty years have elapsed since M. Thomé de Gamond first attempted to prove that a submarine thoroughfare, between the two countries, was possible ; but gigantic advances have been made, during the interval, no less in opinion than in science and mechanics. No international fears are now created by the Mont Cenis excavation, or the Suez Canal. They are regarded, indeed, as treaties and pledges among the Powers of civilization. The shores of the Atlantic have been united by a cable ; the barrier of the Alps has been virtually destroyed ; and, with reference to the latest and, perhaps, grandest project, a careful geological survey has shown, at any rate, the possibility of cutting a tunnel through the narrowest, or almost the narrowest, part of what are sometimes designated as the Straits of Dover, a distance of twenty-two miles, or slightly more. Trial borings and soundings taken at different points by Sir John Hawkshaw and the late Mr. Brassey indicate a bed of chalk as the stratum through which, after leaving the coasts on either side, the perforation is to be made. Of course, on the freedom of this bed from accidental fissures, dislocations, and "faults," the success or failure of the vast experiment depends ; but there is every reason for believing that it lies in a mass, continuous and compact, between, as it were, two impenetrable ramparts of clay. From the boring on the English coast, in St. Margaret's Bay, a great unbroken depth exists,—175 ft. of "upper" chalk, and 295 ft. of "lower" or gray, chalk which is occasionally confounded with the clay itself ; while the workings on the French side, near Sangatte, show 270 ft. of the upper, and 480 ft. of the lower. Experimental shafts, on a narrow scale, resembling somewhat the borings for an artesian well have been carried to a depth of 600 ft.; but these supplemental demonstrations, in point of fact, were superfluous, the main object being to ascertain the depth and nature of the Channel bottom, which, at its deepest, is 180 ft., and its average rather more than 100 ft. below the surface of the water. No sudden changes of profundity, and no reefs or banks, are discernible, to the knowledge of the most experienced men, and the bed of the "thin streak" is shown to be a gradual and almost equally rising and falling concavity between the two coasts. Under these conditions, as the reports inform us, and taking into account the deep homogeneous strata to be bored—about 500 ft. thick—not less anywhere than 200 ft. between the crown of the arch and the bed of the Channel (allowing for the precipitous cliffs on either side)—every hope may be entertained that the enterprise, though so incomparably superior in its magnitude to that of Isambard Brunel for constructing a Thames subway, will be successful. The Thames Tunnel was, indeed, in some respects, a more hazardous enterprise. Little was then known about sub-aqueous boring ; the materials were more shifting than those which the Channel excavators will have to encounter,—irregular strata of loose earth, masses of sand, gravel, mud, and clay, liable to constant disturbance ; and a formidable tidal action. In rememberance of these obstacles, it was thought that a tunnel beneath the sea must present insuperable difficulties. But we have gone through the great submarine galleries of the Cornish, Cumberland, and other mines, and observed

no more drip than would be evident in any cavern of the Derbyshire Peak. For instance, the mine of Shiel Lode runs to a length of 80 fathoms below the level of the sea, at a depth of less than 18 ft. from the water. It has never been inundated, nor have the workmen (workwomen also, we are sorry to add) suffered through deficiency of ventilation, space, and provisions for their comfort. To conclude, practically, however, the first boring is to be about 9 ft. each way, which dimensions are asserted are the least that can be depended upon as a test, or even as an experiment. Then will follow the work of enlargement, along the walls and roof, through the agency of a machine which, it is affirmed, can bore chalk at the rate of a yard, or more, an hour. A difficulty, however, may still have to be met. The most costly labor of any will be the removal of the excavated stone, clay, and soil. Tunnels driven underground have usually shafts, at intervals, through which the disturbed earth is raised, and their frequency, by enabling the excavation to be broken up into short lengths, reduces considerably the arduousness of the work. Such advantages, however, will not exist in the case of the projected Channel Tunnel. All the earth, or rock, or clay, or chalk will have to be removed to the terminal shafts at either end, and this toil and expenditure must increase as, by progression of industry, the headings are removed to greater distances from the ends. Nevertheless, the task is now fairly in hand, and we may rely upon the spirit and the genius of the age in which we live to carry it through effectually.

RELATIONS OF TITANIUM TO IRON.

By RICHARD AKERMAN, of the Stockholm School of Mines.

From "Iron."

Titanium occurs in many iron ores, and sometimes in very large quantity. Thus a magnetic iron ore from Ulfö, in the Archipelago of Angermanland, contains, according to an analysis by Dr. A. Tamm, 9.51 per cent. titanic acid. Further, Herr Fernquist has found in a magnetic iron ore from Taberg, near Jönköping, 6.30 per cent. ; and in a magnetic iron ore from Longhult Mine, in Smoland, 8.5 per cent. titanic acid. Finally, in similar ore from Inglamola, in the same province, 5 per cent. titanic acid has been found.

Titanium is very difficult to reduce, and the incomparably greatest part of an iron ore's content of this substance passes in the furnace process into the slag, the color of which, in consequence, becomes dark to completely black, while in the pig-iron produced it is commonly difficult to detect the least trace of it. Thus Herr J. E. Eklund, in an examination made at the Stockholm School of Mines, found scarcely a trace of titanium in the pig-iron produced from the ore from Taberg, mentioned above ; but the slag belonging to it, on the contrary, contained 8.55 per cent. titanic acid, and another furnace-slag from Taberg ore has been found to contain 10 per cent. titanic acid.

Professor Eggertz, too, while assaying very titaniferous iron ores, has never succeeded in obtaining any titanium in the pig-iron produced. Nor did any success attend an experiment made in Percy's laboratory to produce titaniferous iron by fusing together oxyde of iron and finely pulverized titanic acid in a graphite crucible, inasmuch as no titanium was found in the metallic buttons produced; but Sefström on the contrary —probably in consequence of stronger blowing, and the higher temperature thereby occasioned—obtained a very titaniferous iron by heating, in a graphite crucible, a mixture of oxyde of iron and titanic acid, and a similar mixture along with the bisilicate of lime. In the former case he obtained a very hard but malleable iron, with 4.78 per cent. titanium ; and in the latter a velvet black soft iron, with 2.2 per cent. titanium.

In a third experiment, similar to the second, there was obtained an unmalleable white and hard pig-iron, with 0.5 per cent. titanium. That this substance is sometimes also found in pig-iron produced in the common way appears from the fact that Mr. Riley, after several unsuccessful trials with different varieties of pig-iron, finally found, in several which were produced partly from titaniferous bog ore from Ireland, very considerable contents of titanium, or from 0.5 to 1.6 per cent. Further, Rammelsberg has found a small content of titanium in a spiegeleisen from Lohhütte, in Müsen, and finally Karsten says that a trace of titanium may be found in many varieties of pig-iron.

Besides occurring in the furnace-slag, titanium is also found in copper-colored compounds which are found most frequently in the form of small cubical crystals, but also in an uncrystallized state, partly on the bottom and walls of the furnace, partly in the so-called pig-iron clots, and partly also in the slag itself. These were at first believed to consist of metallic titanium, but, according to Wöhler, their composition is represented by the formula $TiC^2N^2, + 3Ti^3N^2$. This compound of titanium may, according to Herr Zincken, be volatilized at a high temperature, and its occurrence is by Wöhler considered to be connected with the formation of the cyanide of potassium in the furnace.

In the dry assay of titaniferous iron ores there is commonly observed between the pig-iron and the slag, and also around both, a copper red film, which, in all probability, also consists of the compound of titanium just mentioned. Karsten further states that he also found in pig-iron small red grains, and that it is only in the pig-iron in which they occur, that any noticeable content of titanium is found, in consequence of which he doubts whether iron and titanium can enter into any true chemical combination with each other.

Ores, rich in titanium are, as has already been mentioned, specially difficult of reduction, so that the quantity of fuel required for their dry assay is much greater than when other ores are employed, and this circumstance may perhaps be explained in this way, that the titanic oxyde or acid indirectly increases the difficulty of reduction, inasmuch as it tends to retain a part of the oxyde of iron in combination with itself. When the black slag obtained in the dry assay from titaniferous iron ores, has been fused several times in succession, in a graphite crucible, small buttons of pig-iron have, according to J. Akerman, been obtained every time ; but the remaining slag has been still of the same degree of blackness. It is also remarkable that titaniferous iron ores are often smelted in a graphite crucible with the same result, whether they are fluxed with lime or quartz.

The salts of titanium are fusible with difficulty, on which account titanium makes a charge difficult to smelt; but, notwithstanding all this, it may yet be a question if titanium is not favorable to the formation of spiegeleisen. It cannot be considered as absolutely established, but it is a fact, that spiegeleisen can very readily be produced from Taberg ore, notwithstanding the small quantity of manganese (0.4 per cent. protoxyde of manganese); and this ore, notwithstanding its richness in magnesia (18.3 per cent.) and poverty in iron (31.5 per cent.), differs from the Swedish ores only in this that it contains a litttle vanadium and a great deal of titanium. Somewhat larger percentages of manganese have indeed sometimes been found in Taberg ore than that mentioned above ; but that the fitness of this ore for the production of spiegeleisen must be derived from some other cause than the common one—that is to say, the presence of manganese—is believed to be shown by the fact that two pieces of spiegeleisen from different works in Taberg district, analyzed at the Stockholm School of Mines, contained 0.15 to 0.2 per cent. manganese ; and it appears probable, therefore, that either vanadium or titanium is the cause wherefore spiegeleisen is so easily formed from this ore.

Ulfö ore has, in consequence of the difficulty of reducing it, been used only to inconsiderable extent, and, as far as I know, no spiegeleisen has been produced from it ; but that it tends to give a white pig-iron appears from Clason's experience that when not more than 19.4 per cent. of a basic charge, which previously gave dark gray pig-iron, was at

Bollsta furnace exchanged for Ulfö ore, the iron became white, with only here and there a gray speck interspersed. Titanium may possibly therefore favor the tendency in iron to combine with the carbon occurring in it; but if this is in truth the cause of the phenomena just mentioned, the action of titanium must be very powerful, for the pig-irons thus produced have been found to contain, as has been already mentioned, scarcely a trace of the substance in question. However this may be, it is worthy of notice that the specimen of spiegeleisen from Taberg has not been found to contain more carbon than common charcoal-pig, and that it is not brittle like other spiegeleisen, but, on the contrary, very difficult to break in pieces.

With reference to the difficulity of reducing titanium, and its tendency to combine with oxygen, it is probable that the titanium sometimes occurring in pig-iron is oxydized during the refining process, and in malleable iron, so far as I know, titanium has never been found.

By fusing together 99 parts of steel and one part of metallic titanium Karsten obtained a good steel throughout, but its content of titanium was very variable; and Karsten finds in this circumstance an additional support to his views that titanium and iron in the metallic state do not enter into any true chemical combination, but are merely mechanically mixed with each other. This steel, after polishing and etching, took on a very fine damascening.

Faraday and Stodart have attempted, by fusing together steel filings and a mixture of charcoal in one case with titanic acid, and in another with titaniferous iron sand, to produce titanic steel. In this way, too, a good steel was obtained which took on damascening, but no trace of titanium could be discovered in it, and this notwithstanding that a specially high temperature was employed for its production.

From what has been stated it is thought to follow that it is only exceptionally that any reduction of titanium has taken place in the case of mixtures of titanic acid or compounds of oxydes of titanium with iron and charcoal. Attempts have been made to produce titanic steel by fusing together compounds of titanic acid with charcoal and iron, but Percy states that many well-known analysts have sought for titanium in such steel without success; and, without setting up for a judge in this question, I may add that I have not found any titanium in such steel. This is also the case with Mr. Riley, who has taken so much trouble with determinations of titanium, and who found so considerable quantities in some varieties of pig-iron.

To how great an extent the titanium crotchet has been carried is best seen from the circumstance that the superiority of Dannemora iron, and other first-rate brands of steel-iron, has been attributed to the richness in titanium of the ores used in their production the fact being that, so far as I know, no titanium has been found either in Dannemora ores or in any of the other Swedish ores, from which the most renowned varieties of steel-iron are produced.

From the facts above stated it appears to follow that if titanium is of any observable use in the manufacture of steel, its influence on the qualities of the iron must be so exceedingly strong that so small a quantity as can with difficulty be discovered by analysis acts upon it; and this is confirmed, to some extent, by the fitness of Taberg ore for the production of spiegeleisen; or the influence of titanium must be indirect, by conducing to the removal of substances hurtful to the steel. This perhaps may be the case, at least so far as sulphur is concerned, for at the furnaces where Ulfo ore is used it is believed that the danger of red-shortness is considerably diminished by a mixture of less than 10 per cent. Ulfo ore in a charge containing sulphur. There are those also who affirm that titanium purifies from phosphorus, but I know of no facts to prove this. On the other hand, it is contradicted by the fact that Dr. A. Tamm has, in the pig-iron produced in the dry assay of Ulfo ore at the School of Mines, recovered the whole of its content of phosphorus, which, however, was so small (the ore containing only 0.07 phosphoric acid) that a final conclusion can scarcely be deduced from this experiment.

The dismissal of European employés on the East Indian Railway has been stopped by the Supreme Government.

THE MAIN DRAINAGE OF PARIS.

From "The Building News."

ALMOST coincidently with the formal completion of the main drainage system in London has been issued a statement from those who may, in English phrase, be termed the Commissioners of the Seine, on a precisely kindred subject in Paris. It begins by contradicting the popular, and especially the foreign, idea that the capital of France is a dry city —asserting, on the contrary, that the average daily rainfall equals half the amount artificially supplied for the consumption of all the inhabitants. Tide floods, which, mingle together, contaminated by the pollutions of streets, of dirty roofs, and all else constituting an infectious flow wherever any population, great or small, is gathered together, must be got rid of systematically, somehow. The gutters, sinks, vertical pipes down the fronts of houses, the gratings and runnels in the streets, were useless without the immense number of subterranean canals carrying off all this excess, at a point far from Paris, into the river, though necessarily not so near to the sea, as are our own sewage outfalls. There is a curious, though not an exact, parallelism between the history of the two systems. That of the English metropolis was ordered by Act of Parliament to be carried out in the year 1858 ; in the same year that of the French metropolis was completed. It is needless to dwell upon the crying necessities which existed for both ; but Paris was, perhaps, in the worse condition of the two. In distant times the state of her streets was an abomination patent to the eyes even of those who looked out from palace windows : in more modern days the evil became so intolerable that wealthy private individuals protected their lives by draining, at their own expense, the thoroughfares in which they resided. Later still, after a storm, the streets of the lower town had to be crossed on temporary wheeled bridges, always kept in readiness ; and, so late as 1839, a petition of the inhabitants represented to the Government that whole quarters would be depopulated if some abatement of the evil did not take place. Even then nearly twenty years elapsed before the grand reform was effected ; but it was a real one, and upon a magnificent scale. The French, who are fond of splendid phraseology, declared that a new or underground Paris had been created ; but, apart from the national habit of verbal exaggeration, it was perfectly true that an immense work had been accomplished in the face of stupendous difficulties. For, at that time, and since, the city was being converted above, as well as below, by means of new streets, squares, public edifices, and railway termini ; and it was, moreover, found that there were three miles of habitations for every mile of sewer. The task at that time taken in hand occupied about nine years in its fulfillment, and the results have been now about eighteen years in operation. That their success has been great, as the Administration asserts, is not to be denied. It has had the happiest effects upon the health, the pleasantness, and even the external aspects of Paris ; but that nothing remains to be done, more particularly in the outer circle of the city, not even the Board, as we should term it, of "Bridges and Roads" attempts to show. Indeed, its primary object in drawing the attention of the Minister to the subject is that he may be induced to support a supplemental plan for bringing within the cope of the Parisian main drainage system the outlying yet contiguous districts, which can scarcely any longer be regarded as suburbs. The undertaking, it is urged, would be neither formidable in the obstacles presented by it, nor costly in the execution, because— the argument is an official one, be it remembered, and not altogether supported by experience—the existing chief arteries, constructed, not to answer the purposes of a generation or two, but designed upon a scale of more than Roman grandeur—literally—are capable of receiving any number of affluents that could possibly be directed into them. In magnitude, of course, they do not approach those of London, but, in every other respect, they are not less remarkable. The entire arrangements is dis-

tinguished under two heads—principal arteries and feeders. Little value is assigned to pumping stations or reservoirs. The French comparison, in fact, is that of a fish's skeleton running beneath the roadway: the dorsal bone is the "collector," the lateral bones are the drains, whether from the houses or the gutters. The former, or the largest of them, follows the lines of the valleys which so characteristically mark the configuration of the French capital, so that they may receive the tribute of the more elevated quarters, and they are three in number:—One, on the right bank of the river, known as the "departmental," on account of its vast extent, the wide basin it drains, and its being regarded as taking precedence of the other two; and this divides into three large branches, gorged by the sewage of the worst quarters—the cattle markets, the public slaughter-houses, the gasworks, the immense industrial establishments of La Villette, Montmartre, Belleville, St. Denis, and even the crowded hamlet of Bondy. Eighteen months ago it was considered more than sufficient for any conceivable accumulation; but it is now affirmed that the outlet into the river not far from Saint Ouen is occasionally so choked that its arch threatens to burst. This, however, it is explained, may be accounted for by the fact that, at a particular point, one *embouchure* carries off the load brought down by two of the vast vaulted subways that intersect subterranean Paris. The second great collector, on the same side of the stream, starts from the Arsenal Basin, and continues its course through, a purer neighborhood, until it reaches the village of Asnières, where it vomits—to employ the word in its Roman sense—its contents into the Seine, to the infinite detriment of waters that would otherwise be delightful. The Government is urged to take this fact into consideration, in conjunction with the municipality, and to relieve, if possible, so favorite a pleasure resort of the Parisians from so noxious a neighbor. For, it is pointed out, besides the crowded tract of town between the Arsenal and the railway, it bears a pestiferous load from the Sebastopol district, the Rue de Rivoli, with all its mansions, hotels, side thoroughfares, and royal dwellings; and elsewhere, including the Place de la Bastille, the Boulevard Malesherbes, &c.; it receives, in fact, the discharge from the great sewer of the Petits-Champs, and the dangerous drain named after Richelieu, which, at the first drop of rain, is choked, and much dreaded by the workmen on account of its steep falls from the higher to the lower level. On the other or left bank of the Seine there is only one "collector," which includes, however, that which was once a pretty running water—the Biviere, which, for many years was the Fleet Ditch of Paris, famous for the abominations it poured (many-colored and fœtid) into the stream which is the pride of Paris, near the bridge of Austerlitz. This also makes an exchange with its parallels beneath the opposite bank, and, after traversing many populous neighborhoods, adds its unclean flood to the Seine.

Thus, in a space of nine or ten years, Paris is reminded it acquired, at a rough estimate, 400 miles of new or renovated drainage, constructed upon improved principles. Formerly its sewers were built of common ragstone, soft, pervious, and perishable; then, of what is called, in the vicinity of Paris, where it abounds, "millstone rock." In 1844 Roman cement was employed for the arching only; but, after 1855, the entire surface of the "gallery" was coated with hydraulic cement, ensuring a solidity and a capacity for cleanliness unprecedented. Few cases of asphyxia, we are told, now occur. The strange phenomena which, in the reign of Louis XIII., were known by the equally strange designation of "basilisks," have been driven away; overgorgings, whether of water or rubbish, are, in the main channels, so rare as hardly to be taken into account. The slopes were, in the first instance, carefully settled, though, here and there, they are in actual course of improvement; and a visit to the sewers of Paris is, in our days, equivalent to a pleasure trip—that is to say, there are certain show sections; but they must not be taken as more than an exemplification of drainage, *de luxe*, beginning with the Place du Châtelet and ending at the Madeleine. They are not, however, to be despised on that account. The gigantic hall, whence branch the grand "canals," leads to underground

roads, whence, looking up, the eye is attracted by a series of metal conduits, black and polished as ebony, which carry across this twilight highway the waters of the Ourcq and of the Seine itself; and, farther on, of the Vanne—engineering works of which the French are not unjustly proud. Along the sides of these Titan tunnels run the tubes of the pneumatic dispatch; in the thickness of the wall are offices for clerks and lamplighters; lights enclosed within porcelain globes hang from the iron columns; there are rails and trains through the long perspective of semi-darkness. But this, as already suggested, is little in connection with the practical drainage works. A little further on, and sewage barges float upon a stream which calls up an idea of the classic Acheron. They are manned by the pilots of a singular navigation, which shuts and taps as it passes the several districts, and so in a manner regulates the general outpouring. A distinction will here be seen, broad and unmistakeable, between the London and the Paris systems, even if only mechanically considered. But, we may repeat, the subterranean Paris exhibited to visitors does not comprise all that might be shown—at least to observers of a more practical class. The attention of the Minister is drawn by the original engineer of the works that, since they were nominally completed, twelve different types of drains have been experimented upon; the grand "collector," with its broad sideways, the hollow within a hollow, leaving room for cleansing and the search after lost valuables; the drains from private houses, generally very steep in their descent towards the central "collector;" and seven or eight other varieties in form and size. As to size, it is scarcely possible to exaggerate the precautions that are necessary when a tempest of rain occurs. In July, 1872, a storm broke over Paris, accompanied by a startling fall of rain; the great running vault beneath the Rue Rivoli was, within a quarter of an hour, full; the water burst through the street gratings; many workmen were swept away; and, even now, notwithstanding the superb proportions of "subterranean Paris," five minutes' flood will imperil the city. It is by no means asserted by the memorialists that the principle of the Paris system is defective. On the contrary, they insist upon its architectural spaciousness and massiveness, its capacities of out-throw, and its power of "collecting" the superfluous waters of a storm. But the "statement"—it might be wrong to speak of it as a report—although we have used the term "sewage," really says very little concerning sewage at all. It is nearly all confined, as were the plans of M. Belgrand's engineers, to the carrying off of superfluous water. There is nothing, or scarcely anything, said to the Government about the *exuvia* of the city; yet suggestions are made vaguely in respect of this vital question, since, as the report (if so it may be termed) puts the point plainly, a system of main drainage, which is made also a plan of promenades, cannot be very practical except before being employed." But, it adds, a great advantage is gained through the power of, at any time within a few hours, shutting off and drying up a part of the extraordinary labyrinth for purposes of examination or repairs; and a special characteristic is the machinery employed—invented, indeed, since the ostentatious opening of the works—for the lifting up and disposal of such extraneous offal as masses of stable straw, hanged cats, drowned dogs, and unfeathered mattresses, the amount of which, the commissioners say, "stupefied us." Another and more tragic aspect of these vaulted highways might be alluded to, but it is unnecessary. In the parts, it is officially affirmed, which are not liable to inspection by strangers, every possible experiment is, even now, being tried, so far as regards arches of a marble unity, walls exuding and absorbing little damp, floors impermeable to any moisture except that which they carry away, and the fluted earthenware pipes, which, according to the same authority, act as final adjuncts to the rest. Another, and even a grotesque, aspect might be given to the subject by the grave reflections bestowed upon that which has generally been regarded as a ludicrous aspect of the Parisian main drainage—the rats. The sewers of Paris engender these vermin in their worst and most ferocious form, and, incredible though it may seem, they were

long under a kind of official protection for the sake of their skins, which afforded a great supply to the kid-glove-making trade of the capital, and to various other industries of that versatile metropolis, which are not yet, perhaps, sufficiently understood. This, however, at the best is only a parenthesis. It is important to know that, according to the appeal addressed to the Minister of State, the example of London is at last quoted, and that the produce of the Parisian sewers will, before long, be spread around in endeavors to further irrigate and fertilize the long-exhausted districts around.

But for the moment it suffices to appreciate the enormous and complicated works which, upon a scientific and practical representation to the French Government, it is at length proposed to complete.

THE USE OF STEEL.*

By J. BARBA, Naval Constructor at Orient.

So much remains unknown regarding the nature of steel, so much that is desirable to know and is presumably discoverable, that every new claim to fresh information on the subject of steel is regarded with interest provided the source is trustworthy.

The little work of M. Barba, just translated by Mr. Holley, bears in the names of the author and translator, sufficient guaranty of its superior value. Although the author dwells mostly upon the uses of steel in large structures, his remarks upon the nature of the metal and the classification of the grades and kind are so appropriate, and altogether interesting, that copious extracts from this part of the work will, we trust, find favor with the reader.

Mr. Holley's preface, setting forth the present condition of the steel problem, we first give almost entire.

"There are two groups of facts regarding the modern steel business, which especially concern the American manufacturers and users of this material.

1st. Three French men-of-war, built out of Bessemer and Martin steels, were so successfully constructed in 1873 that three more large ships were ordered in 1874 to be built from the same materials. Several Bessemer works in England are running exclusively on a general merchant product having a large range of grades and uses, and taking the place of both crucible steel and wrought iron. The Continental works are turning probably a third of their Bessemer product and nearly all their Martin product into other forms than rails. All the late locomotives—many hundreds—on the London and North Western Railway are built of Bessemer steel, excepting only the wheels and necessary castings. Everywhere, abroad, Bessemer and Martin steels are more and more extensively and satisfactorily employed for ship and boiler plates, beams, channels and angles for ships, bridges and other structures, railway tires and axles, general shafting, agricultural implements and the multitudinous forms of machinery bars, and forgings. In the railway and machine shops, the bridge works and ship yards of Europe and of France especially, the method of treating steel—of heating and shaping it and building it successfully into machinery and engineering structures, has become, what it must everywhere become, before this material can be employed to the best advantage, a distinct and highly developed art.

2d. In the United States, out of a Bessemer product of 350,000 tons per year, probably less than 6,000 tons are used for other purposes than rails. Very few Bessemer works have any machinery for producing the various constructive shapes required, or any experience in making steel of high or low grades. Bessemer manufacturers are talking about reducing products, in the fear that rail orders

* "The Use of Steel for Constructive Purposes; Method of Working, Applying and Testing Plates and Bars." By J. Barba, Chief Naval Constructor at l'Orient. Translated from the French, by Alex. J. Holley, C. E. New York: D. Van Nostrand.

will fall below the capacity of their works. Martin steel is now made in American works, regularly and successfully, of all grades, from springs down to boiler plates, thus furnishing every constructive grade required. Engineers and machinists are generally asking for just such material as steel has proved to be abroad, but are yet hesitating about the use of steel, because our Bessemer manufacturers have not got much into the way of making other grades than rail steel, and Martin manufacturers have not until quite recently begun to adopt those improvements in plant and practice which will make steel cheaply ; and also because our artisans have not in most cases made any study of the art of working steel, and are therefore afraid of it. Experts say that the use of wood, not only in ocean vessels, but in river and lake boats and barges, must soon give way to the use of metal, as it has done abroad and is beginning to do here; and there are thousands of wooden bridges on our railways and highways which must soon be replaced by metal ; so that for these two large uses, not to speak of general machine construction, there is growing up a vast market for a better material than iron. Excellent pig for the production of cheap steel is obtainable in all parts of the country, and ferro-manganese, upon which important qualities of constructive steel depend, is now cheap enough to warrant its general use.

In short, with every facility for making the products so largely needed here, and so largely used abroad—with the best steel works in the world, and working organizations in them which have increased product and decreased cost in a remarkable degree, we are devoting more concentrated action to schemes for preventing over production than we are to adapting grades and shapes of product to the various constructive uses, and to teaching artisans how to heat, shape and apply them.

In view of this state of affairs, it seems to me that the dissemination among our steel makers and users, of the facts contained in M. Barba's little book, should be of great advantage, 1st, to our engineers and machinists, by making more conspicuous the nature of steel and of the new and important art of working steel ; 2d, to the managers and owners of large enterprises in construction and transportation, by revealing to them the fact that steel is such a tractable and valuable material ; and 3d, to our steel makers, by showing them that a vast want exists for products which they *can* make, and what kind of steel and treatment of steel will enable them to take advantage of this existing want.

It is to be regretted that M. Barba did not give us the analyses of the steels employed—not even their percentages of carbon. This addition would have made his work complete. But by comparing the tensile resistance and elongations of the steels he mentions, with those of other steels from the same works and with Belgian steels, of which I have analyses and mechanical tests, I judge the materials put into these French ships to have had between 0.25 and 0.33 per cent. of carbon. These or even lower steels can be readily and uniformly produced in our Bessemer works, while Martin steel can be made as low as 0.10 carbon without difficulty.

It is very interesting and important to note that steels which harden and temper as readily as these do, and which hence so readily acquire dangerous internal strains, can be made so completely tractable and can be so insured against fracture in manufacture and use, by proper manipulation and by heating at the right times—additions to the ordinary iron-working processes, which are not so very costly when works are once fitted out with suitable apparatus.

Another important fact demonstrated at the Barrow works in England (set forth by Mr. Josiah T. Smith, in a late paper before the Inst. of Civil Engineers), and most completely proved by these French experiments, is that the injury done to steels of rail grade and below, by cold punching, is confined to the skin of the hole ($\frac{1}{100}$ inch thick in this case) ; and that this injury is only hardening by pressure which may be completely removed by tempering or annealing, or by reaming out this thin ring of hardened metal. The manner in which this was proved, is a commentary on the nicety of French experimenting.

It has not probably occurred to many boiler-makers who could do nothing with these grades of steel, and so have con-

demned steel altogether, that shearing and locally hammering plates put them in a condition similar to that produced by cold punching, which reduces the strength of the parts most affected, above 20 per cent. Nor has it perhaps occurred to engineers who believe in steel and are anxious to give it a fair chance, to dispense with that class of smiths and boiler makers who cannot be told anything about the treatment of steel, and will not yield to any new requirements—just as these French engineers turned out the skilled workmen who could not treat plates and bars without cracking them, and substituted carpenters, who being willing to follow instructions, made a success from the start.

The adaptability of steel to constructive purposes is specially shown in stamped work, such as pieces shaped like a low-crowned hat, of which 700 were produced without losing one, while not one good piece could be stamped out of iron. The facts that steel crystallizes less than iron by heating without working, and that steel plates have practically the same strength with, and across the "grain," are greatly in its favor.

The hardening of beams and angles of comparatively uniform section, in the last passes of the rolls, is demonstrated, and this should be a rebuke to those engineers who insist that a rail is as unlikely to break when it has a very thin flange which must come out of the rolls at a dark red heat, as if it had a thicker flange which would finish hotter.

The manner in which carbon exists in steel—in solution and in mechanical mixture—also the hardening effects of suddenly cooling steel and of cold hammering, shearing and punching, viz., hardening due to pressure; also the solution and dissemination of carbon by heat, are fully treated in this work, and will doubtless make clear a subject which in many practical minds has been more or less indefinite if not mysterious.

The more important conclusions as to treatment, to which the author comes, and to which the artisan in steel will have to come, and which are also set forth by Mr. Krupp and other steel makers who have pushed their wonderful products against the tide of "practical" conservatism into vast constructive uses, are:

1st. Avoid local pressures in working cold steel.

2d. If local pressures must occur, remove their effects by annealing—not once, but as often as dangerous pressures are produced.

The rationale of this treatment is obvious; steel is more dense than iron, hence it must be more humored in its cold treatment. But when it once gets into working shapes without internal strains, it is much stronger and safer than iron.

It should seem that such careful, thorough and obviously trustworthy experiments as those detailed in this book, and the conclusions to which they inevitably give rise, should prove a stimulus to our steel makers, to enlarge the range of manufacture rather than to curtail production because their one specialty may possibly exceed the present demand—and to engineers and to constructors of government works, to take a leading part in all efforts to adapt the new material and its treatment, rather than to wish them well from afar off."

Thus far Mr. Holley presents the question.

The French author discourses at length upon the "Composition of Steel," and upon the "Classification of Steels," in separate chapters, from both of which we herewith present liberal extracts:

COMPOSITION OF STEEL—ITS CHIEF PROPERTIES—TEMPERING AND ANNEALING.

The metals designated in the trade as cast iron and steel owe their characteristic properties to the presence of a certain quantity of carbon either mechanically mixed or in solution with the iron. These metals may contain other substances more or less affecting these properties; chiefly phosphorus, silicon, sulphur and manganese. But neither of these substances is necessary to the constitution of cast iron or steel. It is sufficient to mention that they are present in most of the irons of commerce, without studying the considerable influence they may exert.

Putting aside, then, all considerations relating to the presence of foreign matters, cast irons and steels are carburized irons. Carbon exists in them either in a state of solution or of mixture, without forming any clearly defined carburet.

"Steel is a solidified solution of carbon in chemically pure iron. This solution in a liquid state is not saturated except in case of the steel which contains the maximum of carbon which iron can hold in solution. Cast iron is a saturated solution of carbon in iron, with an excess of carbon in a state of mehanical mixture. It might be defined as steel containing carbon in mechanical mixture. In this state (mixture) the amount of carbon is larger, in proportion as that held in solution is smaller, or as the total quantity of carbon contained is greater. So gray cast iron is a slightly carburized steel with much carbon mixed, and white cast iron is a more carburized steel with less mixed carbon."

The phenomena of the solution of carbon in iron to form steel, group themselves around the four following principal laws :

1. The quantity of carbon iron can contain in solution is greater as the temperature increases.

2. By slow cooling, part of the carbon is separated from the solution and remains in a state of mixture.

3. By rapid cooling or by a sufficient external pressure, the greater part of the carbon is maintained in solution. Rapid cooling acts in this case by the pressure resulting from it. If the carbon is mixed, an external pressure produces a solution in greater or less proportion according to its intensity.

4. The temperature at which melted steel is solidified decreases in proportion to its richness in carbon.

These laws of the solution of carbon in iron conform to those which regulate the solubility of solids and gases in liquids.

1st. The solubility of solids generally increases with the temperature.

2d. When a solution made at a high temperature is cooled, part of the solid is separated.

3d. The solution would probably maintain itself under a sufficient pressure ; but no experiment has been made on this subject, to my knowledge ; a trial, to verify this point, would probably be very difficult of execution, on account of the enormous pressure required. The solubility of gases increases with the pressure.

4th. Finally, solutions are generally solidified at temperatures decreasing as the solutions become more intense.

The rapid and slow cooling of heated steel constitute tempering and annealing, two operations which play an important part in the use of the material.

When any metal is tempered, that is to say, rapidly cooled, the external layer cools first, and it does this all the quicker as the difference in temperature between the body and the liquid in which it is immersed is greater. The conducting power of the liquid used has also a great influence on the rapidity of cooling : tempering in mercury, for instance, will be more intense than tempering in water.

This cooled external layer contracts and presses strongly on the inside, which is yet at a high temperature ; reciprocally, it receives from the inside the same pressure. Another phenomenon is a consequence of this contraction ; in order to contain the internal volume, the external layers must stretch at the expense of their elasticity ; if the tempering has been intense enough they may exceed their limit of elasticity and stretch permanently. If tempering has been incomplete or slight, this limit not being reached, the extension will be but momentary, and will disappear when cooling is complete.

It is known that these phenomena are practically taken advantage of, to break cast iron blocks, which could not be easily effected by blows ; they are heated red and cooled in a stream of water. The external surface contracts and passes its elastic limit ; as it is capable of only slight stretching before breaking; cracks show themselves on the surface, and a comparatively light blow is sufficient to break the block into several pieces.

During the second period of tempering, the cooling spreads to the centre. In their turn, the central fibres contract on account of the lower temperature ; but they are bound to the external fibres which have exceeded their limit of elasticity; they must then stretch at the expense of their elasticity as they contract; they, at the same time, cause a contraction of the external fibres.

A tempered body is therefore subjected to direct forces which are balanced by molecular tensions. The forces which exist after tempering can be ex-

hibited by suppressing a part of them. If a bar of tempered iron, squared on all sides, is cut in two longitudinally in a planer, care being taken to hold it in an invariable position, each of the pieces assumes, when left to itself, a curved form, the concavity of which is on the planed side. This form demonstrates a tension in this part, resulting from the second period of tempering. The forces brought into play in the first period would have produced the opposite effect if they alone had acted.

Bodies increase in volume when they are tempered. M. Caron has observed the following variations of steel bars :

TABLE No. I.

	Natural state.	At Red Heat.	After tempering.
Length	20.00	20.32	19.95
Width	1.00	1.03	1.01
Thickness	1.00	1.03	1.01
Volume	20.00	20.00	20.351

In these bars the length decreased and the width and thickness increased ; under the influence of an internal pressure the bar behaves like any homogeneous body subjected to deformation by an internal force ; it tends to assume the spherical form.

M. Caron mentions another instance of a bar of rolled steel :

TABLE No. II.

	Natural state.	After Tempering.
Length	20.00	20.45
Width	1.51	1 51
Thickness	3.70	3.70
Volume	111.74	114 25

In this example tempering has again produced an increase of volume ; but unlike the preceding case, the greatest dimension has increased and the others have not changed. This contradiction is apparent only. It is explained by the lack of homogeneity in a rolled bar which is capable of stretching more readily in the direction of the rolling, than perpendicularly to it. The longitudinal fibres exceed their elastic limit before this limit is attained transversely ; the addition to the volume consists in increased length.

Tempering should produce these effects in homogeneous bodies only, the composition of which does not vary with temperature and pressure. In steels and other carburized irons tempering is complicated by the presence of carbon, the solution of which it partly brings about. It is difficult to know whether the increase in volume observed in tempered steel is to a certain extent modified by this solution ; by continuing the comparison between the laws of solubility of solids in liquids, we may suppose that the increase in volume does not result from this cause ; for a solution never has a larger volume than the total volume of the bodies it contains.

The solution brought about by tempering steel produces a body endowed with properties different from those it possessed before tempering ; but this body, at the time of sudden cooling, is always under the influence of the phenomena we have just explained. The pressure resulting from the two phases of tempering maintains in solution a part of the carbon that would have become separated by slow cooling ; this portion will be greater as the pressure is stronger, and the tempering more rapid.

If a non-homogeneous body is tempered, composed for instance of steels at different degrees of carburization, the action will be complex ; it seems probable that, when the body is hot, the carbon will be distributed a little less irregularly, and that this dissemination can increase only under the pressure of the cooled external fibres. If we suppose this body represented by different tints according to its amounts of carbon in different parts, the lines of demarcation, instead of being decided as in the original state, will be blended after tempering.

This phenomenon of transfusion of carbon through iron or steel heated to a sufficient temperature is well known. A bar heated with charcoal is cemented, or dissolves carbon first on the surface, then more deeply, and finally to the centre, if cementation lasts long enough.

When steel is subjected to different degrees of tempering, the carbon is kept in solution in a much larger proportion, as tempering is more energetic. With each class of steel, there should correspond a degree of temper at which the maximum effect is produced, that is to say, when tempering would cause the solution of all the carbon contained in the steel. If the effort of contraction were the same for all steels, the intensity of temper producing this effect should increase with the degree of carburization. But the contraction or pressure due to rapid cooling is generally insufficient to produce this result. The more the rapidity of cooling is increased, the more the steel changes its properties. The least carburized steels only could be excepted; beyond a certain point the solving effect produced by an increase of intensity in tempering ought to be nothing; alternations in elasticity only could be observed. But, in these bodies, the limit of elasticity is reached under relatively slight effects, and tempering, by a variation of temperature such as we can effect, does not produce a sufficient pressure to dissolve all the carbon

Tempered bodies generally regain their properties when they are annealed, that is to say, when they are made to cool slowly after having been heated sufficiently. When a homogeneous body, the composition of which does not vary by heating, is annealed, the effect is merely to restore its original elasticity. To insure thorough annealing, the operation must be performed at a sufficiently high temperature, and the cooling must be slower as the size of the body is greater, so that there may be between the interior and exterior, but a slight difference in temperature. The first condition is necessary to allow the metal to recover the elasticity it lost in tempering; the second condition should prevent in the successive phases of cooling, the production of undue strains.

In complex bodies like steel, the effect of annealing is complex; besides this restitution of elasticity to the fibres altered by tempering, it produces the separation of a part of the mixed carbon. This separation must take place equally throughout the mass to render the bodies homogeneous after annealing; and it is easily understood that a very slow cooling is necessary to insure this result. For large pieces of steel, this cooling must occupy several days, sometimes several weeks.

When steel is properly annealed, the different molecular tensions previously produced are suppressed; the fibres relax under the influence of heat, and return to their first elasticity.

If annealing is applied to a piece having undergone local tempering, the effect will be the same. In a bar made up of steels of different degrees of carburization, annealing will establish a little more homogeneity. Owing to the high temperature the bar will have to bear, the lines of demarcation will no longer be as clearly defined, and the difference between the several parts will be less, as the piece is exposed longer to the fire. In annealing, this more regular dissemination of carbon is due only to the high temperature to which the piece is raised, while in tempering, the effect is increased by the pressure resulting from rapid cooling.

Annealing must not be performed at too high a temperature,—near the melting point,—less the fibrous texture of the metal acquired by forging, should be changed; slow cooling would crystallize it, and it would then have no elasticity,—it would be burned.

In the same steel there may exist a series of intermediate states between the natural state and the state corresponding to the maximum temper it can take. The several properties of the same steel follow a continuous law of variation between these two extreme points. In the natural state, steel possesses a hardness increasing as it contains more carbon and as it approaches more and more the maximum of saturation. Tenacity, or resistance to breaking follows the same law, increasing in a continuous manner from soft iron to the hardest steel.

The stresses steel can bear before reaching its limit of elasticity follow the same law. On the contrary, the attainable stretching increases when the quantity of carbon and consequently the hardness and tenacity increase. The welding properties vary like the stretching qualities; they are very high in slightly carburized irons, and are reduc-

ed to almost nothing in steels rich in carbon.

When steels are tempered under the same conditions, hardness, tenacity and stretching follow the same law that obtains in the natural state ; hardness and tenacity increase with temper, and ductility decreases. In short, the difference between a steel in the natural state and the same steel tempered is less as carbon decreases and as the metal approaches pure iron.

We will consider here, only temper obtained by rapidly cooling steel heated to a high heat in a cold liquid. Under these conditions the changes of constitution induced by tempering should decrease as the operation is performed on less carburized steels. With very high steels, the elastic limit is reached under a very heavy load only ; with soft steels the elastic limit is much more quickly attained ; the same degree of cooling will then produce a contraction and pressure much smaller in the second case than in the first.

From this statement we may conclude that, whenever hardness and tenacity are required, and a material liable to deformation before breaking is not desirable, the highest or most carburized steel must be used ; from this class is chosen the steel for tools that are not worked under blows. For constructive purposes where a more elastic material is needed, less carburized iron, in other words, soft steel must be used.

We can conceive that tempering followed by annealing might be used to improve certain more or less carburized iron, especially to restore homogeneity lost in the different stages of manufacture. All merchant irons contain slight quantities of carbon, and consequently yield, but in a less degree, to the influences of tempering and annealing. Heat produces in iron, a more complete solution of the carbon and a dissemination of that mixed in the metal ; probably also of other foreign ingredients. The pressure which follows tempering increases this dissemination. Finally, while annealing, the heat continues the effect produced, and slow cooling allows the molecules to group themselves so as to nearly remove the several internal strains.

In a great many cases tempering is followed by such an incomplete annealing as tends to lessen the molecular tensions, while preserving in the metal the greater part of the properties due to tempering, viz., hardness, tenacity, and also a more homogeneous composition. Afterwards more or less annealing is given according to the degree of elasticity which is to be restored.

Partial annealing after tempering is used in armor plates. The tempering they undergo after rolling renders them more homogeneous throughout their mass, by the compression it produces in every direction. Hardness, or resistance to the penetration of projectiles is increased, but the metal becomes brittle, as the tempering is more complete, or, with the same range of temperature, as the plates are thicker.

Complete annealing would destroy all brittleness ; but in order to preserve some hardness and prevent any internal crystallization, annealing is carried only to dark red ; this temperature is insufficient to restore to the different fibres, all their elastic properties, but it allows a preservation of the greater part of the hardness proceeding from tempering.

In plates measuring less than 20 centimetres (.787 in.) in thickness, this annealing is sufficient for the purpose mentioned ; the result is a metal able to withstand the penetration of projectiles and rarely breaking under their impact. In thicker plates submitted to tempering and annealing under the same conditions, the molecular tensions after tempering preserve more value after annealing; the places satisfactorily resist penetration; they, however, have considerable brittleness. To avoid this defect, it would be necessary to give more intensity to annealing; the plates would then offer less resistance to penetration, but they would no longer break under blows.

The same result ought to be attained by reducing the intensity of temper; the heat to which the plates have to be raised cannot be lessened, since, in order to obtain homogeneity, a solution of all foreign matters in the iron must be produced ; but the rapidity of cooling can be diminished by using a liquid which is a less good conductor than water, or by raising the temperature of this water. By this latter means the heated piece will be subjected at first to a rapid cool-

ing to prevent separation of the carbon from its solution, then a much slower one, to prevent extreme molecular tensions.

These considerations are verified by M. Caron's recent researches. In laboratory experiments he has succeeded in bringing to the same degree of hardness, tenacity and elasticity, some steel springs tempered and annealed by the ordinary process, and others simply tempered in hot water. He expresses himself as follows, upon his experiments :

"Tempering in hot, or rather boiling water singularly modifies soft steel containing from $\frac{2}{1000}$ to $\frac{4}{1000}$ of carbon ; it increases its tenacity and its elasticity without sensibly altering its mildness."

M. Caron, in experiments reported in the same article, succeeded in regenerating burned iron by tempering it in a hot liquid ; he used a solution of sea salt heated to 110 degrees centigrade. The primitive texture is then restored to the metal by the strong pressure due to tempering and the drawing out of the fibres which results from it. The slow cooling following this first effect, allows the fibres to recover the greater part of their elastic properties, notwithstanding the previous rapid cooling. It is well known that burned iron is restored by raising it to a white heat and submitting it to an energetic hammering. It will be seen that tempering acts the same as hammering; it constitutes a real forging action, producing a drawing out of the metal. It follows from this that the quality of cast ingots might be improved by a series of temperings which would bring them to the same state as if they had undergone a preliminary forging or rolling. We have not been able to verify this deduction, not having steel ingots at our disposal.

CLASSIFICATION OF STEELS—SOFT STEELS USED AT L'ORIENT AND BREST—TESTS.

The various properties of steels—their resistance, their stretching, the manner in which they are affected by tempering —furnish a convenient way of comparing and classifying these metals ; it would be difficult to do so, practically, by taking their composition as a basis.

Until a few years ago, steels more carburized, and much more liable to the defects pointed out above, than the very soft metal now manufactured, were generally used. The substitution of ferro-manganese for spiegel, to produce carburization at the end of the Bessemer process, or in the Siemens-Martin furnace, has contributed to the production of materials containing very small quantities of carbon, though free from the oxydes of iron that the manganese was designed to reduce or remove. To distinguish this steel from the one they had previously put in the market, the manufacturers have given it the name of *métal fondu*, or *cast metal.*

The steel used in France and England in building large ships may always be classified among soft steels ; but France alone has so far, we believe, worked cast-metal on a large scale.

The constructors of the English navy demanded for their steel plates a tensile resistance of 32.9 tons per square inch in the direction of the fibre, and 29.8 tons perpendicularly to the fibre.

The resistance should in no case exceed 39.9 tons per square inch.

For the ships built at L'Orient and Brest, where cast metal alone has been used, the minimum tensile resistance required was 28.5 tons per square inch, with a corresponding stretching of 20 per cent. at least. For deck beams made up of I bars, $11\frac{13}{16}$ in. deep, the lowest limit of stretching was put down to 18 per cent. in consideration of the difficulties of manufacture. The plates were furnished in nearly equal quantities by the works at Creusot and at Terre-Noire. The I beams were manufactured by MM. Marrel Bros. of River de Gier from Terre-Noire steel ; the other rolled bars and beams were furnished by the Creusot works.

The steels were manufactured at Terre-Noire by the Bessemer process, and at Creusot by the Siemens-Martin process. Both these great works have succeeded by means of numerous tests, and the certainty of their manufacture, in furnishing soft steels of obviously even quality. They can, however, vary, at the wish of the buyer, the properties of their products. The bars subjected to test were all turned to 3.93 in. in length, the section being 0.31 square in. Tempering was done in oil, the bars being heated as unformly as possible to a temperature corresponding to bright red.

The steel furnished to the Government works at L'Orient and Brest, offering a minimum tensile resistance of 28.5 tons per square inch was to reach its limit of elasticity only under a heavier load than 13.94 tons. Estimating that iron plates reach this limit of elasticity under a load of 10.4 tons per square inch., which is rather above the average, it will be found that, in construction, an iron plate of thickness e' can be replaced by a plate of thickness e' determined by the relation :

$$22\,e' = 16.5\,e, \text{ or } e' = \tfrac{3}{4}\,e.$$

This is the case only when the plates suffer a direct tensile strain. An iron plate 0.47 inch thick can then be replaced by a steel plate 0.35 inch thick.

At L'Orient, all the tensile tests on Creusot or Terre-Noire steel were made with a scale built by M. Frey, having a range of 0 to 25 tons (Fig. 1). The test bars, a sketch of which is given in Fig. 2, were brought to a uniform section for a length of more than $7\frac{7}{8}$ inch. Each end was wider than the body, and these different widths were connected by easy curves. In the outline, great care was taken to avoid any angle in which a rupture might originate. At each end holes were drilled allowing the bars to be connected to the jaws of the testing-machine by heavy pins. The beam of the scale was always kept horizontal for this purpose, the lower fixed point of the bar was moved down while the stretching was taking place. The tensile strains were obtained by loading successively one or the other scale beam ; they were gradually increased, 44 lbs. at a time, leaving a certain interval of time between each increment of load to give to the successive elongations time to develop themselves.

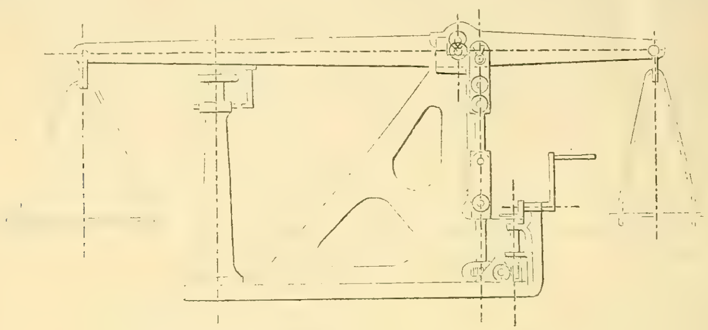


FIG. 1.
Scale for Measurement of Tensile Strains.

FIG. 2.—Test Bar.

To ascertain the limit of elongation a length of 7 in. was defined by two centre punch-holes ; on these marks were fixed the extremities of a small apparatus (Fig. 3) ; this apparatus was frequently applied, and indicated by its graduation the successive elongations. An observer followed the travel of the index, and noted after each rupture, the figure given by the instrument, also the load put on the scales. These tests were always made by the same men.

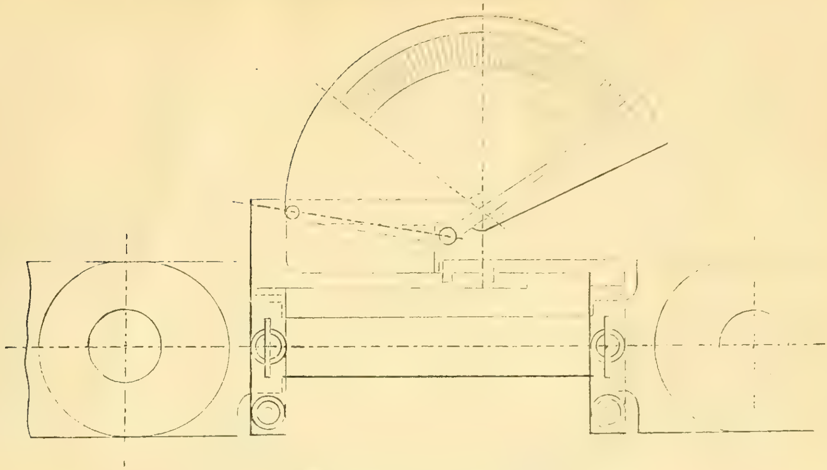


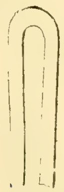
FIG. 3.—Measurement of Elongation.

Besides these tests of tension, the toughness of the metal was frequently ascertained by bending strips cut from plates or bars; this was done by hammering only on the extremities of the specimens and never where flexion was taking place; the bending was stopped when the first crack appeared and the results obtained were noted and kept as a basis of comparison. Sometimes the bending was done under a hydraulic press, thus allowing work without blows; the specimens so tried gave the same curves as those bent by the hammer under the conditions just described.

The Steels from Creusot and Terre-Noire subjected to these different tests did not give the same results; it was therefore important to repeat them, in order to determine the relative value of the products.

The grain of the metal (as shown by fracture) indicated at first sight, a slight difference; in order to examine it, nicks were made in plates and beams with a chisel; the use of a sledge was avoided, as it might have altered the grain; the specimens were then broken as usual by bending. The Bessemer metal showed a very fine grained break, slightly slate colored, and approaching the fracture of steel proper; by tempering, the grain became still finer, the color or brightness not varying sensibly. In I beams, the grain was a little more steely than in the plates. The Martin metal from Creusot gave a finer grained fracture, whiter and brighter; it approached more by its brightness and color the fracture of fibrous iron; tempering did not modify it in a very appreciable manner. In every case the grain evinced the greatest homogeneity, at every part of its surface.

Some strips were cut on a planer from plates from both makers; the mean de-



4.—Bessemer. Natural State.

5.—Martin. Natural State.

6.—Bessemer. Tempered.

formations (Fig. 4) were obtained on a series of Bessemer plates, and (Fig. 5) on a series of Martin plates.

Figs. 6 and 7 give the mean deformations obtained after tempering, and Figs. 8 and 9 after tempering and annealing.

7.—Martin.
Tempered.

8.—Bessemer.
Tempered and annealed.

9.—Martin.
Tempered and annealed.

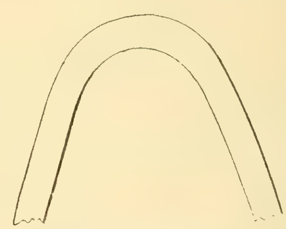
Tempering was done by heating the plates to cherry-red and dipping them into water at 50° Fahr. Annealing was obtained by heating to cherry-red. These experiments were made on specimens 0.31 inch thick for Bessemer metal and 0.35 inch thick for Martin metal; the trial was consequently a little harder for the latter.

Martin steel bore the bending test in the natural state, a little better than Bessemer steel; the difference was slight, but very decided after tempering, and we notice from this stand-point a marked inferiority in the products from Terre-Noire. Finally, after annealing, elasticity was obviously restored to what it was before tempering.

Strips cut out of I beams gave in the natural state, the average deformations, Fig. 10, when cut from the flange, 0.53 inch thick on the average, and Fig. 11

10.—Fers en H.
(Flanges, Natural State.)

11.—Fers en H.
(Web, Natural State.)



12.—Fers en H.
(Flanges, Tempered.)

when cut from the web, 0.42 inch thick. After tempering, cracks were observed when the specimens were of the form Fig. 12 for the first, and Fig. 13 for the

13.—I beam, Web Tempered.

others. The I beam metal, chiefly in the region of the web, seems to experience by tempering an alteration in elasticity much more prominent than that observable in Bessemer plates under similar circumstances.

Two series of tensile tests made on plates, angles, and I beams gave the following average results:

Table IV.

Untempered Steel.

	Resistance to Rupture per sq. inch of the original section.	Per cent. of Stretching.
Bessemer Plates....	31.60	20.2
Bessemer I Beams..	32.81	19.5
Martin Plates......	28.69	24.1
Martin Angles.....	29.00	21.7

A few more tensile tests after tempering were made at L'Orient. Tempering was done in the manner described above for the trial strips.

The result was as follows:

TABLE V.

	Resistance to Rupture in tons per square inch of the original section.		Per cent. of Stretching.	
	Lengthwise.	Crosswise.	Lengthwise.	Crosswise.
Bessemer Plates....................	30.95	30.83	22.9	21.9
Martin Plates......................	29.88	30.07	24.2	23.5
Bessemer I Beams..................	33.39		21.1	
Martin Angles................. ..	30.45		24.5	

TABLE VI.

	Resistance to Rupture in tons per sq. inch of the original section.	Per cent. of Stretching.
Bessemer Plates ...	44.22	
Bessemer I Beams.	47.69	6.4
Martin Plates......	34.58	

A few more tensile tests were made after tempering and annealing. It was observed that annealing, well done, restored to the metal in every case its previous tenacity and elasticity, as modified by tempering.

Finally, by trying these different products with a file, it was noticed that the I beams were the hardest to cut; then came the Terre-Noire plates; the Creusot plates and angles were obviously softer than the preceding. After tempering hardness could be classified in the same order.

We may then conclude from these different experiments that Terre-Noire steels have more resistance to rupture, more hardness and less elasticity than the Creusot products; they are much more modified by tempering; in short they evince the characteristics of more carburized iron. Moreover, the rolled beams seem a little more steely than the plates from the same origin. It is hard to explain this fact, without knowing all the circumstances attending manufacture. It may be that the plates undergo in the heating furnace a more decided decarburization than the beams; the thin plates present in the last heatings, with the same volume, a larger surface to the action of flames that may be slightly oxydizing.

The remaining chapters of this valuable treatise relates chiefly to the more technical matters of treatment of plates, beams and angle bars, both in manufacturing and in the processes of punching, drilling, riveting, &c., during the progress of their employment in building. We must leave these chapters for another occasion.

ON RIVER GAUGING AND THE DOUBLE FLOAT.

BY S. W. ROBINSON, Professor of Mechanical Engineering in the Illinois Industrial University.

Written for VAN NOSTRAND'S MAGAZINE.

IN the October number of the Magazine will be noticed an article by Gen. H. L. Abbot on the "Hydraulic Double Float," in which numerous references are made to my paper on "River Gauging and the Double Float," which appeared in the August number. I feel called upon to make mention of the General's article for two reasons: 1st, because I feel highly complimented by its receiving attention from one so distinguished as he, and hence should return my willing tribute of thanks; and 2d, to correct the impressions which his remarks may

have induced, in regard to a few points in my article.

The facts brought out by my investigations, given in the article referred to, I think I stated in as mild terms as consistent with the facts themselves; and without aiming to detract, in the least, from the real value of the very important work reported upon in the "Physics and Hydraulics of the Mississippi River," because I consider the work and the report as exceedingly complimentary to its authors, as well as a most valuable treatise on River Hydraulics. The discovery that the mid-depth velocity is unaffected by wind currents, I regard as of great importance and value; and which, alone, is worthy of the issue of a book. But having found, by my investigations, that a correction should be applied to double float observations whenever, and wherever made with a large connecting cord in use, in order that the observations be reduced thoroughly in keeping with science, I felt prevailed upon, on account of the great labor involved, to make it public, with a view to aiding such as may desire to use the double float, or to study observations made with it.

The General sets out by saying that he will correct a few misapprehensions into which I have fallen; the most important one, as appears from his remarks, being the "entire inapplicability to the Mississippi River, of the equations." In reply to this I must say, with all due regard, however, for the General's honesty in defending his supposed faultless reduction of the Mississippi observations, that I did not in the least misapprehend the matter; that it was in studying the results of the float observations of the Mississippi itself that I became convinced that when a large connecting filament is used between the floats, the resulting observed velocity should be corrected; that on completing my formulas I found, by applying them to the Mississippi observations, they gave a correction; that, at the time of publishing my article, I had not applied them to any other observations; and as there appears to be no good reason why the formulas should not apply with equal force to the double float when used in Mississippi River water, as well as in the water of any other river, "we are not left in doubt as to their entire" *applicability* to the Mississippi observations.

I must contend that I have *proved*, not merely stated, to any one who has carefully looked over my article, that the best and most truthful results, obtainable from double float observations, can only be realized by including, among others, the needed correction for the connecting cord, and this proof I cannot give up for a statement only. When, for instance, as pointed out in the article, four-sevenths of the actual float area, presented to river current, is made up of the cord itself, every part of which, for great proportional depths, is in swifter water than the lower float. How can there remain a trace of a doubt of at least some slight resulting influence acting to hurry along the float combination? That the float velocity should be materially modified by the presence of a large connecting cord, in an instance like the above, is so self-evident, even were it unsupported by vigorous analytical proof, that the description of the bobbing flag is insufficient to effect the burden of proof without accompanying figures showing the *unmistakable* and *exact* position of float, the *precise* depth of river at the very point, and the length of float to its *extreme bottom;* and even then, if one or the other *must* be doubted, can it be otherwise than the figures defining the conditions of the float as to proximity to bottom, rather than the entire absence of action of the current upon more than half of the float area?

Again, if a cord nearly a quarter of an inch in diameter is ever necessary, as represented by the General to have been on the Mississippi, it may be safely employed by simply providing for its errors. This may be done by an empirical method as well as by analysis. But the fact that it is necessary can, it is plainly evident, be no guaranty that the current will not act upon it, nor that it will be exempt from correction.

The criticism in regard to neglecting the masses of the floats, if it applies, must be with respect to a correction which I made no attempt to elucidate; and, hence, another error which the Mississippi observations are subject to. The observations which I treated were supposed corrected for all errors except that due to the large cord and upper float.

Also, if the pulsations and whorls exist, their action upon the cord would crook it into unaccountable curves, every one of which would shorten the distance between the floats, and prevent contact with river bottom; and, hence, an argument by the General himself against his own theory of touching of bottom by lower float, and consequent oscillation of upper float and flag. If, therefore, my formulas err at all, they err on the side of giving too few corrections, instead of erring on the side of "entire inapplicability to the Mississippi River."

The modern watch or clock needs regulating that it indicate correctly, so the meter needs its coefficient of velocity. But who, at the present day, would throw away his watch or clock in preference for the sundial, because the latter needs no coefficient of velocity?

Also, the General makes the statement with considerable force that Gen. Ellis finds the float and meter to "give sensibly the same result," an argument of his own in favor of the meter. Again, just before that, he says that the efforts to determine the curve of velocities "utterly failed" till the double float was used. But why should the meter have failed if it gives sensibly the same result as the float?

In my article, my formulas were only applied to observations taken in the Mississippi River, where a large connecting cord was used. To show how the errors disappear when a fine wire is used, agreeably to the requirements indicated in the discussion of my formulas, I have computed some of the corrections for the float observations, made by Gen. Abbot himself in a feeder of the Chesapeake and Ohio Canal, and given on page 253 of the Mississippi Report, where the upper float presented an area of a quarter of a square inch, and the lower float 17 square inches, the floats being connected with a "very fine wire." Depth of canal, seven and a tenth feet; W estimated at 0.005 lb., $C_1=0.75$, $C_2=1.75$. Using data as given, I find

For $y=5$ ft. $x=.08$ ft. $v_2-v_1=.043$
" 6 " .39 " " .061

which show no appreciable rising of the lower float on account of its falling behind the upper, and corrections only about a tenth of those found where the large cord was used, which indicate a decided advantage in use of wire if the observations are to go uncorrected.

Permit me to remark, finally, that I see no cause for altering either my analysis or results of the same, on account of the interesting additional particulars regarding the Delta Survey, which Gen. Abbot has so kindly given in his article.

REPORTS OF ENGINEERING SOCIETIES.

American Society of Civil Engineers.—The twenty-third annual meeting of this Association was held on Wednesday last.

The annual report of the Board of Direction upon the affairs of the Society was read, from which it appears that the increase in membership during the year was 48, and the present number is 492. By donation and purchase, there were added to the Library about 850 books and pamphlets, many photographs and other illustrations of engineering structures. The treasurer's report shows the finances of the Society to be in satisfactory condition; the increase in receipts keeping pace with increased expenditures during the year incident to change in location of the Society rooms.

Officers were elected as follows:

George S. Greene, President.

Theodore G. Ellis, } Vice-Presidents.
W. Milnor Roberts, }

Gabriel Leverich, Secretary.

John Bogart, Treasurer.

Octave Chaunte, Alexander L. Holley, Francis Collingwood, Quincy A. Gillmore, and Julius W. Adams, Directors.

Subsequently the Standing Committees were appointed as follows:

On Finance—Messrs. Roberts, Gillmore and Collingwood.

On Library—Messrs. Holley, Bogart and Ellis.

The Norman Medal was awarded for a paper "Description and Results of Hydraulic Experiments with large Apertures at Holyoke, Mass., in 1874," by Gen. Theodore G. Ellis.

Reports of Committees on "Tests of American Iron and Steel;" "Time and Place of the Eighth Annual Convention;" "Mutual Benefit Society;" and on "Policy of the Society," were adopted. It was determined to hold the next Annual Convention at Philadelphia, June 13th—15th, 1876. The matter of presenting American Engineering at the Centennial was referred to a Committee. A proposition that action be taken towards adopting the metric system of weights and measures was discussed; and amendments to the By-Laws relating to the appointment of Committees to report on professional topics or perform expert service; Annual Conventions being declared business meetings; making Past Presidents of the Society members of the Board of Direction; holding social meetings at the Society's rooms during the winter; and other matters were considered and duly referred.

The Annual Dinner was held at Delmonico's

—Gen. Theodore G. Ellis presided and informal speeches were made by Messrs. Roberts, Briggs, Holley, Bloor, Western, Thurston and others.

The American Association for the Advancement of Science, on Weights and Measures.—The special committee of this association, to which this subject was referred, report upon the steps taken the past year for the establishment and perpetuation of the basic units of the metric system, and the results of the conference of delegates from twenty-one nations. The United States was represented by Prof. Joseph Henry, of the Smithsonian Institute, and Julius G. Hilyard, of the Coast Survey (now President of the association). The original standard meter and kilogram were adopted, and steps taken for authentic reproduction of them for distribution, and for comparison with other standards of dimension or quantity. The report comments upon and lauds the co-operation of our executive government in this great effort for universal civilization, and asks from all scientific bodies an expression of opinion to urge upon Congress the monetary aid desirable to meet the national share of the expenses; estimating the same at $12,000 original appropriation, with about $1,000 per annnm subsequently. The committee say: "It is to be considered, that this is not designed merely to advance the interests of the metric system of weights and measures, or to serve as a means of promoting the extension of that system. The design is higher than that. To secure the universal adoption of the metric system, would be undoubtedly to confer an immense and incalculable benefit upon the human race; but it would be a benefit felt mainly in the increased facilities which it would afford to commerce, and to exactness in matters that concern the practical life of humanity. On the other hand, to secure that severe accuracy in standards of measurement which transcends all the wants of ordinary business affairs, yet which, in the present advanced state of science, is the absolutely indispensable condition of higher progress, is an object of interest to the investigators of nature immensely superior to anything which contemplates only the increase of the wealth of nations. . . . . ."

A series of resolutions were offered by the committee, and were unanimously adopted by the association. Those of our readers who are interested especially in the metric system, will find this report in full in the proceedings of the association, which will shortly be published.—*Franklin Institute Journal.*

IRON AND STEEL NOTES.

Mr. David Mushet states in his paper on "Iron and Steel," that 4 tons of coke was the quantity of fuel employed about the year 1810 for each ton of pig iron made in Great Britain. In Shropshire it was ascertained, about the year 1840, by Mr. William Jessop that the quantity of pig iron made amounted to 82,750 tons, consuming in its manufacture 409,000 tons of coal, or nearly 5 tons of coal to each ton of pig iron. In Great Britain, in the same year, Mr. Jessop further ascertained that the quantity of pig iron made amounted to 1,396,400 tons, consuming 4,877,000 tons of coal, or an average of 3½ tons of coal to each ton of pig iron manufactured. In July, 1867, the commissioners appointed by a Royal Commission in the previous year to inquire into the question of the probable duration of our coal-fields and their resources, began the important inquiry entrusted to them, and periodically for five years pursued their investigation. This investigation of the Coal Commission, as regards the statistical inquiry, was entrusted to the late Sir Roderick I. Murchison and Mr. Robert Hunt, Keeper of Mining Records, and forms vol. iii. of the Coal Commission Report, consisting of nearly 500 pages. The deductions drawn from this report show that in the year 1869 the quantity of coal employed in the manufacture of a ton of pig iron amounted to 3 tons in Great Britain, and the inquiries subsequently instituted by the Mining Record Office show that in Shropshire in the years 1872 and 1873, it amounted to the like quantity, while taking the average of Great Britain in the same years, 1872 and 1873, we find that 51 cwt. of coal was the quantity used in the making of each ton of pig iron.—*Engineer*

The Iron Trade.—The iron trade is at present passing through one of those crises which appear to arise once every six or seven years in its history. Naturally the danger is most threatening where there has been the most rapid growth and expansion—namely, in the North of England. The condition of the trade was, perhaps, never more perilous, nor required greater prudence and judgment on the part of those responsible for its welfare. Several heavy failures have occurred, and more will undoubtedly follow if the tide of doubt and suspicion which has set in be not quickly stemmed. When bankers suddenly withdraw the facilities which have for years been ungrudgingly granted to a hitherto thriving and prosperous district, the effect may be in some respects beneficial, but it may be purchased at a cost which those who produce it may find somewhat expensive.

The question is, Is the iron trade really unsound? Has it ceased to be a profitable staple, and is the present depression likely to be lasting?

It is undoubtedly a trade liable to severe alterations of adversity and prosperity, but, on the whole, it has been signally prosperous, and has advanced truly by "leaps and bounds."

In 1852 the capital embarked in the iron trade in the North of England did not exceed £300,000 and the whole manufacture of iron did not exceed a value of £500,000. In 1874 the capital employed in the trade was variously estimated at from £5,000,000 to £6,000,000 while the value of pig-iron and manufactured iron produced amounted to £15,000,000. The growth of the Middlesborough, Stockton, and Hartlepool has been one of the most remarkable features of the past quarter of a century.

Of the £6,000,000 of capital now sunk in machinery, plant, buildings, &c., fully £5,000,-

000 has been the result of untiring industry and thrift. Scarcely a moneyed man has ever come into the district, and it is a curious fact that, except two, there is not yet a gray-haired man in the iron trade in Middlesborough, Stockton, or Hartlepool.

This great growth has been several times arrested, and despairing croakers have been as prophetic of evil things to come in years past as they are at the present moment. But after a year or two of dulness there has been the invariable rebound, enduring for several years, when manufacturers have flourished, and the producing power of the district has been largely developed.

Profits have been invariably spent on additional works, and when, as happened in a recent case, bankers shut up their pockets, the struggling manufacturer has to go to the wall, although it is confessed, if his works and plant could be turned in a month's time into cash—which is impossible—he would have sufficient to pay his creditors 40s. in the pound.

In 1852 there was a general impression that pig iron, which in the early part of the year was 36s. per ton, would never see 40s. again. By the end of the year the price was 65s. per ton, all other descriptions of iron advancing in similar proportions.

In the panic of 1857 a similar state of affairs supervened.

In 1866, when all English railways fell into discredit, it was generally believed that the iron trade had passed its highest powers of demand and production, and that no good could be expected from it again. Pig-iron fell to 51s. per ton, and remained there for a long time ; but in 1871 we saw it at 140s. and such a demand accompanied this price that a large stock of nearly 700,000 tons was cleared off, while production itself had made unprecedented strides.

For a year and a half the trade has been in a languishing and unprofitable state. Manufacturers have lost money, but not a fleabite of their earnings. The bad debts of merchants have, on the whole, not been serious.

When the worst has come the tide turns, and there are symptoms that the dullness which has pervaded the whole commercial world is beginning to lessen. Wherever civilization spreads iron will be in request, and there is no reason to fear either that as a great staple of this country it will be in less request or that any other country can beat us in the race of competition.

If the timidity of some and the shortsightedness of others should cause the present depression to be the cause of widespread ruin and disaster in a district which has been remarkable for its industry and integrity, it will indeed be a matter of very great regret.—*London Times.*

RAILWAY NOTES.

Paris Tramways and Railways.—On their next assembly, the Paris municipality are expected to apply for powers to construct a new line of tramway from Porte-Maillot to the Bridge of Suresnes, passing through the whole length of the Bois de Boulogne. Tramway extension in Paris has proceeded at a rate which seems to indicate a high appreciation of the value of the old Roman motto, *Festina lente.* The Vincennes tramway was authorized on February 10th, 1854, and opened to the public August 25th, 1875, after a delay of twenty-one years, six months and seven days. Proceedings at the present moment, however, are active enough. Since January, besides the line from the Louvre to Vincenne the Compagnie des Omnibus have began that from the Point de Boulogne to Saint-Cloud, and from la Villette to the Place de l'Etoile ; while the Compagnie des tramways-nord began the lines from Courbevoie to Suresnes, from Saint-Augustin to Levallois-Perret, and from the Place Pereire to Neuilly. Three other lines are being made from la Villette to the Place du Trone, from the Place Clichy to Saint-Denis, and from the Place Saint-Germain-des-Pres to Clamart, while plans are being drawn for two others, one from the Place de l'Etoile to Saint-Augustin, and another from Courbevoie to Reuil. Railway communications between Paris and the suburbs are becoming little by little easier and more abundant, the last section, 14 kilometres long, of the short railway from Paris to Vincennes and Brie Comte-Robert, with a total length of 36 kilometres, was opened on August 5th last, the first concession for the railway bearing date August 17th, 1853. On August 7th last another suburban railway, that from Bondy to Annay, connecting the line of Soissons with that of Avricourt, was inaugurated. This connection, 8 kilometres long, will be thrown open with the least possible delay.—*Engineer.*

Brake Experiments.—In consequence of a statement made by one of the principal officers of the Midland Railway Company, with reference to the collision at Kildwick, to the effect that the engine-driver of the mail train would have been able, with the means at his disposal, if traveling at the rate of fifty miles per hour, to stop his train in 400 yards, certain brake experiments were made, in the presence of Captain Tyler, on the Derby, Castle Donnington and Trent line, on the 21st ult. There were four trials. In the first of these experiments all available means were used to stop the train, viz., tender-brake and one guard's van-brake at rear of train applied, sand used, and engine reversed and steam against it, with the Le Chatelier tap open. The gradient was level ; the train, the total weight of which was 102 tons 7 cwt. 2 qr., was running at the rate of 49.9 miles per hour when the brake was applied. The result was that 54 seconds were occupied in stopping the train, which, after the application of the brake, ran a distance of 807 yards. In the second experiment all available means were used except reversing the engine ; gradient, 1 in 330, up and level ; speed, 49.9 miles ; time occupied, 60 secs.; distance run, 843 yards. In the third experiment all available means were used, and when the engine was reversed, the regulator was allowed to remain wide open all the time ; gradient, 1 in 220 down ; speed,

52.5 miles; time occupied, 55 secs.; distance run, 867 yards. In the final experiment all available means were used. When reversing the engine the steam was first shut off, then the lever pulled into back gear, and then steam was turned on again as in first experiment; gradient, level; speed, 52.5 miles; time, 50 secs.; distance, 787 yards. The weather was fair, and the rails slightly greased. Captain Tyler, in his report to the Board of Trade, states that the engine-driver of the mail train, who at present awaits trial on a charge of manslaughter, could not have acted so promptly as these who on the experimental train listened for the word of command. He adds that instead of 400 yards 800 yards should have been stated as the distance in which, with the assistance of the guard, he would have stopped his train.—*Iron.*

ENGINEERING STRUCTURES.

The Tunnel under the London Docks.—The works on the East London Railway, by which the line will be extended from the present terminus at Wapping to the Liverpool Street Station of the Great Eastern Company, are now rapidly approaching completion, and it is expected that the extension line will shortly be opened for traffic, when there will be through communication between Liverpool Street and New Cross, where the line forms a junction with the London and Brighton and the South-Eastern lines. The most formidable engineering portion of the works is the tunnel under the eastern basin of the London Docks, which has just been completed. The water communication between one side of the basin is restored, and vessels of large tonnage may now be seen berthed in the basin immediately over the submarine railway which has been formed. Operations were carried on by means of coffer-dams and dredging trenches in the bottom of the dock until the London clay was reached. The driving of the piles and the construction of the walls of the coffer-dams was one of the most formidable portions of the work. The arches of the tunnel are of the ordinary horseshoe shape, built with seven rings of brick, and are surrounded with three feet of puddled clay. About two-thirds of the Shadwell Station are already completed, and the covered way northwards, in continuation, is also nearly all finished to about 50 feet north of Commercial Road. The retaining walls for the Whitechapel Station are also nearly finished, and the station itself will soon be completed. The line continues from Whitechapel Station to its junction with the Great Eastern line at Brick Lane, and the works at this point, which are comparatively light, are actively proceeding. The whole of the works have been designed by Sir John Hawkshaw, and are being caried out by Mr. Hunt, the resident engineer. The estimated cost of the works is set down at £500,000 per mile.

The Eighty-one Ton Gun.—The trial of the 81-ton gun took place the other week, at the butts within Woolwich Arsenal. The weight of the shot first fired was 1250 lb. and the charge of powder was 170 lb. It took twelve men to ram the charge home, and the shot was elevated to the mouth of the gun by hydraulic apparatus. The gun was fired by means of electricity. It was found that the shot had penetrated 45 feet of sand, and that the gun had a recoil of 23½ feet. A second shot was fired with a charge of 190 lb. The distance of penetration was over 50 feet, and the recoil 32 feet. The experiments were attended with great success, and no flaw was detected. So satisfied were the authorities of the Royal Gun Factories that the gun would prove a success that application has been made to the War Office for permission to construct four other guns of the same weight, and on precisely the same plans, and the preliminary forging and other preparations for these are already considerably advanced. This gun, which may be considered as an experimental piece of ordnance, is bored to a calibre of 14½ inches, and the walls are consequently much thicker than they will be when the tube is bored out to a diameter of 16 inches, while the strain upon the gun will of necessity be increased by every addition to the powder charge, which it is intended to augment gradually up to 300 lb. This is 60 lb. more than has yet been fired; but the strain has been carefully calculated and provided for with a margin of endurance to spare. So well has experience qualified the authorities to calculate results that the velocity attained by the gun in its its first round was foretold as 1390 feet per second, and it proved to be 1393 feet, within 3 feet of the velocity worked out. The length of the gun is 33 feet, and its diameter varies from about 2 feet at the muzzle to about 6 feet at the breech. Internally the bore measures 27 feet. The gun is not to be fired in its present state any more, but it has many more trials in store; its whole lifetime will, it is expected, be a series of trials, for, while its sister guns are being manufactured to go on service in the ironclad fleet, the four next for the turrets of the *Inflexible*, this, the original gun, will be devoted to experiments for the benefit of science.

Water Contrivances in India.—The contrivances used in India for raising water, and for other purposes, are of a rather primitive kind, and our engineers have something to do to instruct natives in some of the simplest of our appliances. A pump, as we have it, is comparatively unknown, a kind of chain pump being used, with pots or leather bags attached. These primitive appliances sometimes frustrate the calculations of our engineers unaccustomed to them, and a few facts may be interesting, which Mr. Lowis D. A. Jackson, in his "Hydraulic Manual" furnishes us with. Our English mode of bucket baling is unknown in India. Instead of this, the natives use a flat kind of dish, made of leather, or wood bark, rendered water-tight, and stiffened by a frame. At each side cords are fastened, the ends of which are held by two men, who, by a quick mode of dipping and swinging, raise the water to the receptacle above. For clearing foundations where there

is swinging room it answers very well, the lift being generally about 5 ft. About 400 cubic feet of water per hour, or 20,000 gallons per day of eight hours, may be raised. The "beam and bucket" contrivance is a rather more scientific appliance for raising water by hand labor. It consists of a large earthenware vessel suspended at one end of a beam, which is rather thick, and so poised on a fulcrum by a counterweight at the other end, that the force of one man may easily raise the vessel when full.

The "picotah" of Southern India is a development of the principle; a long tree becomes in this case the balance-pole, which is worked by the weight of a man, who walks or runs up and down along the heavier arm of the lever. Another man manages the vessel, and the height of the lift is sometimes as much as 20 feet. The smaller appliance previously described we find can raise 82 cubic feet per hour, or about 4,100 gallons per day. Another similar contrivance is called the "dal," or "jantu." This consists of a wooden trough or gutter working on a pivot. It is worked usually by cords. As much as 21,000 gallons can be raised by this simple means in a day, and a lift of 5 feet, with two men, can be performed. Another very primitive method of raising water is by the "mot," which is a vessel made of ox-hide, bound to a wooden hoop, raised and lowered by a cord over a pulley by oxen, the animals performing the work by descending an inclined plane, and the bucket sometimes emptying itself by a catch cord. A more advanced mechanical appliance, like the ancient chain of pots used in Egypt, Syria, and by the Romans, is called the "Persian Wheel." It is composed of two endless ropes, united and passing over a wheel, the endless ropes hanging a little below the water in the well; earthen or leathern vessels are attached to the loop, which, after being filled, discharge into a trough through the vertical wheel, which is double. Motion is given by a vertical shaft, turned by bullocks. Our modern chain pumps are constructed on this plan. This last appliance is undoubtedly more economical as a labor-saving machine, and is used largely in Northern India. This appliance, lifting 40 feet, will raise 16,500 gallons per day, if it has a double chain of pots. All these methods, however, require a good coefficient of reduction to be applied, as an amount of work is lost by leakage, imperfect construction, &c.

ORDNANCE AND NAVAL.

The "Castalia."—England's insular security is gone. Against an invading force we thought we had the iron-clads. What that amounted to the *Iron Duke* has shown. Still there was the *mal de mer*. But in the *Times* recently we find a jubilant epistle from a Frenchman, who came over from Calais in the *Castalia* in a heavy sea on the previous day, and whose only abnormal sensation during the voyage was a tendency to drowsiness. Capt. Dicey really appears to have achieved a great success, and left the *Bessemer* nowhere. All classes of Her Majesty's subjects, chief constructors at shipbuilding yards, artists, medical men, clergymen, lawyers, ladies, crowd the columns of the *Times*, and all with the same story, the absence of sea sickness on board the twin ship, owing to the absence of pitching, and the very slight rolling or tremulous motion experienced. Other minor causes of nausea, such as the smell of the engines and the closeness of the cabin, are reduced to a minimum. The only drawback is want of speed, which would probably be helped by the use of more powerful engines.

Submarine Operations and the "Vanguard."—The attempts to recover the *Vanguard* and the material sunk with her are likely to test to the utmost not only the skill and endurance of the divers, but also the numerous and ingenious appliances for submarine work that have been invented of late years. So far as these have been tried upon the sunken ironclad, they have apparently fallen far short of the necessities of the case. In the first place, although she only lies about seventy feet below low-tide level, the pressure of the superincumbent fluid appears to be too much for the strength of the most competent and well-accustomed divers. The two dockyard men who have been employed in this capacity, and who in powers of endurance and experience are said to be equal to any two members of their amphibious profession in the kingdom, can only remain under water at the depth named, for fifteen minutes at a time, and then come to the surface completely prostrated. The immense dead weight of the hull forbids any hope of raising it by the means which have often proved efficient in the case of lighter ships, and those engaged have spent weeks in a futile attempt to dislodge the vessel's iron masts. It is now proposed to place round these bands of dynamite, and blow them out of the hull, the effect of which will be farther to strain if not break it, and thus to render the success of future attempts to raise the ship still more problematical. She must also from her great weight sink to some extent in the sand on which she rests, however hard that may be, and there must be more or less of a silting process going on from currents even at the depth of eleven or twelve fathoms. In connection with these salvage operations there have been some very interesting experiments made in Cork Harbor with the Denayrouze submarine lamp. When at the bottom of the harbor, the diver who had charge of the lamp read aloud from a newspaper an account of the examination of the prow of the *Iron Duke*, which was distinctly heard through the Denayrouze speaking-tube, an adaptation of a species of popular entertainment at once novel and remarkable. This lamp, which can be lighted under water, is likely to prove one of the most useful aids to submarine operations that has yet been invented, and from the way in which fishes and other marine creatures are attracted to light, it is probable that had the diver in the instance noted been in a less confined locality, he would, like St. Anthony, have had a much larger audience under than above the surface of the water.

BOOK NOTICES

Annual Report of Her Majesty's Inspector of Gunpowder Works. For sale by D. Van Nostrand. Price 50 cts.

This is but little else than a collection of statistics relating to the manufactories of the United Kingdom, together with brief summaries of the laws regulating such establishments.

Gunpowder is used in a generic sense, and includes all manufactured explosives.

Reports of the Royal Commission on Scientific Instruction and the Advancement of Science. The Sixth, Seventh and Eighth Reports. Parliamentary Blue Books.

These reports contain much that is valuable to educators everywhere. Aside from the valuable essays on special branches of education, there is a mine of information in the exhibition of the entire list of duties of instructors and pupils in the schools and colleges of Great Britain. The curriculum of studies of each is given, together, in many instances, with complete sets of examination questions for entering and graduating pupils.

The Apparatus is specified, by means of which the separate topics of Chemistry or Physics are illustrated. Many valuable suggestions to instructors are afforded, especially in the Sixth Report.

Chamber's Elementary Science Manuals. London and Edinburgh: W. & R. Chambers. For sale by D. Van Nostrand. Price 50 cts. each.

These petite treatises are designed to present a fair outline of the different branches of science. Each one is about what would be expected under an article of its proper heading in a large encyclopædia. The authors are prominent men, and are accustomed to presenting scientific truths in a way calculated to instruct.

The series as at present published embrace subjects as follows:

Chemistry, by Alex. Crum Brown, M.D.
Electricity, by John Cook, M. D.
Astronomy, by Andrew Findlater, LL. D.
Language, by Andrew Findlater, LL. D.
Geology, by James Geike, F. R. S.

Discoveries and Inventions of the Nineteenth Century. By Robert Routledge, F. C. S. London: George Routledge & Sons. For sale by D. Van Nostrand. Price $3.50.

This attractive looking book belongs to the class of popular scientific works whose design is to present in pleasing form a kind of information that many people would not otherwise get. The general style of the book is that of Pepper's Play-Books, and, indeed, some of the illustrations are borrowed from those well known repositories of easy science. But the present work covers a somewhat wider range of subjects, and, moreover, deals with later inventions, such as the "Sand-blast" and the "Bessemer Steamer."

The illustrations are very numerous, and quite good. We judge that it will prove to be a good gift-book for boys during the coming season.

Timber and Timber Trees. By Thomas Laslett. London: Macmillan & Co. For sale by D. Van Nostrand. Price $3.50.

This book presents the substance of a course of lectures delivered before the Royal School of Naval Architecture at South Kensington.

As a matter of course, the qualities of the various kinds of timber are specially treated of, while the natural history of the trees is very briefly treated.

We have never seen before such a collection of tables of strength of timber as here; and all seem carefully arranged from fairly tried experiments. There are but few illustrations, but the treatise is full of interesting and valuable matter to all who are concerned in the selection, use or preservation of timber.

Van Nostrand's Science Series, No. 19. Strength of Beams Under Transverse Loads. By Prof. W. Allan. New York: D. Van Nostrand. Price 50 cts.

This important subject is treated to some extent in the standard works on Mechanics. It is too briefly disposed of in such treatises to fully satisfy the wants of a large number to whom the subject is of vital importance.

In too many cases the higher mathematics are employed, and thus the usefulness of much that is well written is lost to the young engineer who is not well up in calculus.

Prof. Allan has treated this subject with reference to the needs of pupils, who prefer from necessity or otherwise, the simplest demonstration that can be considered complete. Graphic methods are largely employed, and illustrative examples are added as an aid to the student. The illustrations are exceedingly abundant and well executed.

The readers of the Magazine have been made acquainted with the quality of their excellent treatise by the published articles in the current volume.

Discourses on Architecture. By Eugene Emmanuel Viollet-le-Duc. Translated by Henry Van Brunt. Boston: James R. Osgood & Company. Sold by Van Nostrand. Price $8.00.

Nearly all of our standard works on architecture are from English sources, and of course inculcate views more or less influenced by national pride, and in too many instances strongly tinged with national jealousy.

The instruction books in particular have presented quite exclusively the rules and designs of English writers and architects.

In this new treatise, we have at least the ideas of a writer who occupies a different stand point, and so far as prejudice is concerned, it is at least not of the kind which is possible in our standard works. That the author is a competent man for the task of presenting the principles of design, may be judged from his record both as architect and author.

The translator says of him: "And here at last is a man who has studied, measured, analyzed, and drawn Greek and Roman monuments in Italy and the Greek colonies, certainly with singular fidelity and intelligence; who has rebuilt and completed the great Gothic Chateau of Pierrefonds, built the town halls

of Narbonne and St. Antonin, restored numerous churches; constructed the fleche and sacristy of the Cathedral of Paris; repaired the fortifications of Carcassone; architect of the works on the Cathedrals of Laon, Sens and Amiens, and the Abbeys of St. Denis and Vézelay; author of the exhaustive 'Dictionaire Raisonnie de l'Architecture Française, du Xe au XVIe Sciecles,' and other works of large research. Thus equipped, M. Viollet-le-Duc appears upon the scene and endeavors to set forth the true principles of design. * * We do not mean to assert that the author has succeeded in all things, but we think it important to give a new publicity to this honest and earnest effort, and to place it side by side with similar essays of literary men and amateurs, that it may do its work with theirs."

The book is in elegant style, and is finely illustrated.

THE NEW METHOD OF GRAPHICAL STATICS. By A. J. DU BOIS, Ph. D., Prof. of Civil Engineering, Lehigh University. New York: D. Van Nostrand. Price $2.00.

The method of Graphical Statics is less widely known in this country than in either France, Germany or Great Britain. In each of these countries text-books expounding the principles of the method are easily obtained. Here the demand for such treatises is just beginning to be heard; and already the value of this branch of science is recognized by the use made by instructors of such published articles as have appeared in this and one or two other periodicals.

Prof. Du Bois is first in the field to present to American Students a systematic exposition of the elements of this important subject.

Beginning with the rudimentary steps, the system is quite completely set forth, so that the learner can easily master the subject without aid from an instructor, providing always that he is familiar with elementary plane geometry and the elements of mechanics. The fundamental principles once learned, the applications to the important problems of engineering are exceedingly easy and rapid.

In the opening chapters of the present treatise, the author thus discourses upon the characteristics of the method:

"The object of the following pages is to call more general attention to a new method for the graphical solution of statical problems, which has during the last ten years, mainly in Germany, been gradually developed and perfected, and which offers to the architect, civil engineer, and constructor, a simple, swift, and accurate means for the investigation of a great number of practical questions. When once thoroughly understood and familiarized, it will be found greatly superior to the graphic methods at present in general use. Thus, for instance, in the determination of the *centre of gravity* and *moment of inertia* of areas and solids; of the resultant of forces either in space or in the same plane, and having the same or different points of application, as also in the resolution of forces generally, the method alluded to will be found of easy and universal application. When applied to determine the strains in the various members of a roof truss, bridge girder, or similar framed structure, it furnishes a system of 'diagraming' which can be applied independently of any special assumptions as to load distribution, which gives the strain in each member by a single line, which is simple and rapid of execution, and which checks its own accuracy. In its application to '*continuous girders*' it furnishes the *only* method of complete solution for variable loading, without calling in the aid of the higher analysis, or having recourse to intricate formulæ and wearisome calculations. Thus, a girder continuous over three or more supports, at different elevations, and sustaining a 'concentrated load' at any point, can be investigated with nearly the same ease and accuracy as one resting upon only two supports. Here especially those already familiar with the analytical method can, by a union of the two, greatly shorten the time and labor usually consumed in such cases.

"To Prof. Mohr, of the Stuttgart Polytechnicum, the new method owes its origin, as well as many of its most important improvements and extensions. But it was not till 1866 that the complete and systematic presentation of the subject by Culmann directed general attention to the subject, and excited general interest.

"During the eight years which have since elapsed, the method has been considerably extended, notably in the treatment of continuous girders above referred to, and the new edition of Culmann's original work, which is soon to appear, and which has been so long promised, is looked forward to in Germany with considerable interest.

"Admirable as Culmann's treatment of the subject undoubtedly is, still for a long time this interesting and useful method failed to meet with that appreciation and recognition from professional men to which it had just claims; partly, perhaps, because of a natural disinclination in old practitioners to relinquish well known and familiar methods, and partly because the treatment of Culmann required for its comprehension a knowledge of the so-called 'Modern Geometry,' or *Theory of Transversals*.

"This method of treatment is, however, by no means necessary. The system admits of a clear and logical development, which can be followed and apprehended by any one familiar with the elements of geometry as generally taught; and to give in just such a manner the outlines of the subject, indicating its most important applications, and thus to bring it within the reach of those in this country for whose benefit it seems so especially designed, is the purpose of these pages."

The book is neatly printed, with the plates so folded in as to open out in the best manner for the references which are certainly necessary.

It is already in demand for class use.

EXAMPLES ON HEAT. By R. E. DAY, M. A. Longmans & Co. London, 1875.

There is no doubt that, in order to give a real, practical character to the teachings of

physical science in our schools and colleges, the working by the students themselves of such problems as they would actually encounter in the every-day life of engineering or other pursuits is of great importance, and in this respect, we are sorry to say, our scientific class-books have hitherto been very deficient. It is in consequence almost impossible for a lecturer, when discussing the expression of any physical law in a mathematical formula, to go into it except in general terms; and between this and the actual use of it for practical purposes there is a very wide gap. A thorough acquaintance with such formulæ can scarcely be acquired by the student from merely reading about them, or seeing them written on a black board, whereas, if he has once worked out numerically a few examples of them, he acquires confidence in their use, and a real grasp of their actual signification. This small volume, which has just been published by Messrs. Longmans, deserves a welcome for these reasons, its object being to familiarize the student with the laws of heat by affording him sufficient exercise, not so much in the manipulation of algebraical expressions, as in the numerical solution of practical problems. We notice, as of special interest to engineers, that it contains examples of the conduction of heat in boiler-plates and the expansion of railway metals, while there are a large number of problems which involve the idea of the connection between thermal energy and mechanical force. As the answers are given to all the questions, the working of the problems is put within the reach of private students.

The value of the book, however, would have been materially increased if the several sections of examples into which it is divided had been headed with the formulæ applying to them, and we advise the author to add them to the next edition. The little work gives evidence of having been most carefully prepared, and we can, on the whole, recommend it confidently to all who, whether as teachers or learners, are desirous of gaining a real, working knowledge of the laws of heat. We trust that what the author has thus succeeded in doing to facilitate the study of heat, he will repeat for the other branches of physical science.—*Engineer.*

MISCELLANEOUS.

TALC has been recommended by MM. Vigier and Aragon for the prevention of incrustation in boilers. It is used on the Paris and Lyons Railway, and it is stated that the quantity of talc introduced into the boiler is about one-tenth of the weight of deposit accumulated between two consecutive blow-offs. It is stated not only to prevent but to loosen and remove old incrustation.

BELGIAN IRON TRADE.—The manufactured iron trade of Belgium is reviving, in consequence of the low rates of pig-iron, and the rolling mills are getting again into work. At Acoz a new rolling and flatting mill—a third one—has been opened, for the manufacture of merchant iron of every variety, in view of the demand likely to arise from the exhaustion of the present stocks of rails. The new mill can turn out 40 tons of finished iron per day of twenty-four hours. The Societé de Sclessen is said to be getting 100 kilos. of pig-iron with 97 kilos. of coke, being the first furnace in Belgium which has obtained such a result.

A NEW METAL.—Gallium is the name given, "in honor of France," to a new element which has been discovered by M. Lecoq, an amateur *savant*, of Bois-Baudran, Cognac. The celebrated chemist, Wurtz, presented to the Académie des Sciences, in its sitting of September 20th, a note on the part of M. Lecoq, announcing the discovery, particulars of which had been communicated under seal as far back as August 27th. This new element has not yet been isolated, and has not therefore been seen by any one; its physical characteristics remain so far unknown. It is an analogue of zinc and cadmium, of which metals it is an alloy, and was found in a blende from Pietrafita, Spain. The forms under which it is known, so far, are those of the chloride and sulphate. The discoverer is a student of the phenomena of the spectroscope, and it was in the course of his observations that the new metal presented itself, its character being revealed by a spectrum which no simple body had ever given. Two lines, one much brighter than the other, both situated in the violet—the region occupied by the brightest lines of the zinc—were noticed, the place of the former line being at the 417th degree of the scale of lines, and the other at the 404th.

The affinities which gallium has with zinc are declared by chemical analysis as well as by its spectrum. Like zinc it is not thrown down from solution in hydrochloric acid by sulphuretted hydrogen; and preserves its analogy with zinc by being precipitated by the same gas from an acetic acid solution. Under these conditions it is obtained before the zinc, and on fractionation, the two are got separately. Like zinc, the new metal gives a white precipitate with the sulphide of ammonium. On immersing a piece of zinc in a solution of the new metal it separates and comes out, not in a metallic form, but under that of an oxyde, precisely as aluminum does under similar circumstances. The analogy with aluminum, however, is not long sustained, for if a small dose of ammonia precipitates the gallium an excess redissolves it. Up to the present time, only a very small quantity of gallium has been obtained, but M. Wurtz, who presented the paper, has given the Academy tubes of solution for experiment; and on asking for a commission to examine into the question and to place gallium on the list of simple bodies, the Academy named M. Wurtz himself, joining with him M. Frémy. The actual number of known elements is 63, 47 of which are metals and 16 metalloids. If the new element takes the place claimed for it, France will have obtained an honor equal to that of England which discovered thallium, and approximative to that of Germany, the discoverer of casium and rubidium.